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THE BRITISH JOURNAL OF METALS

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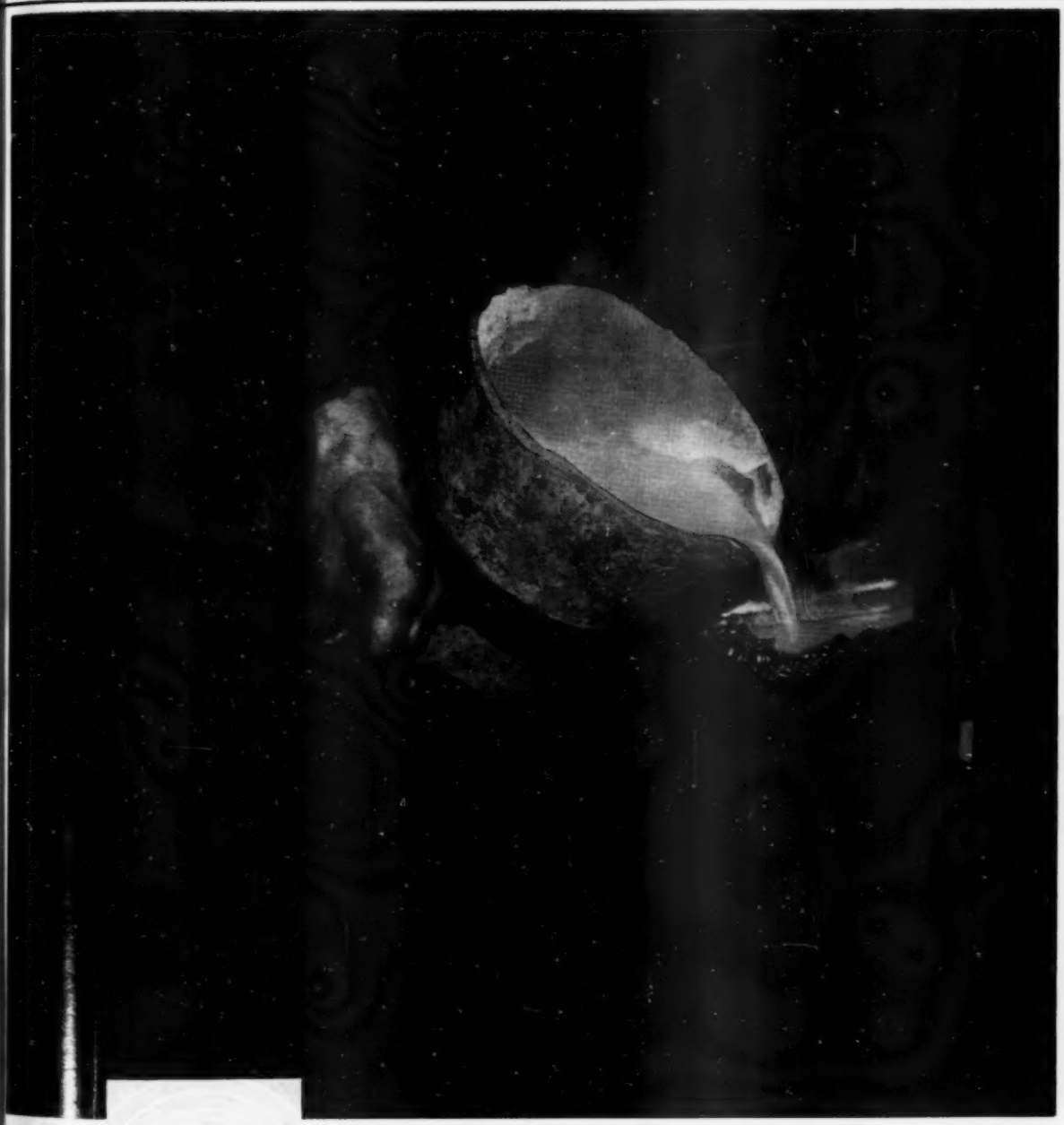

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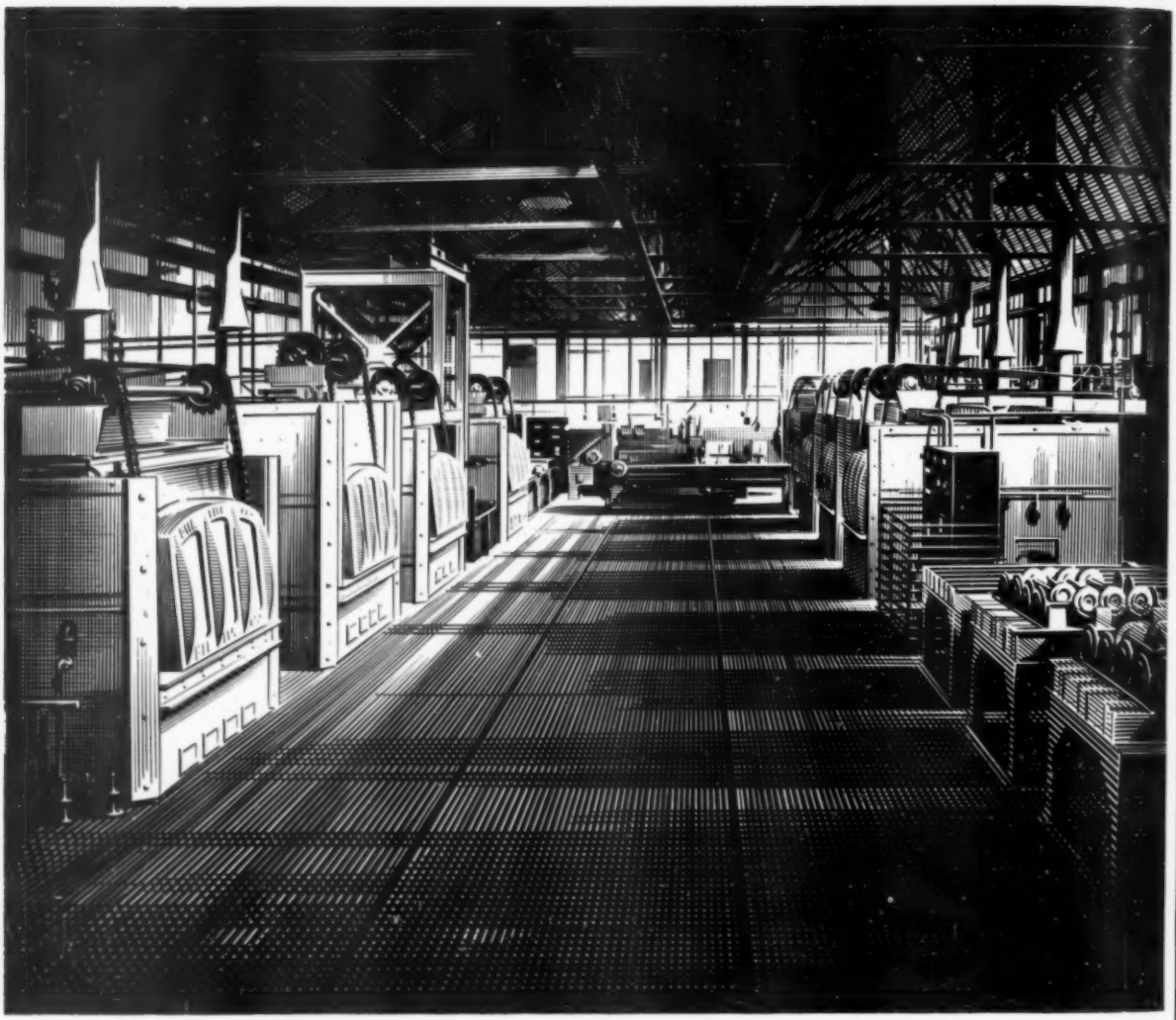

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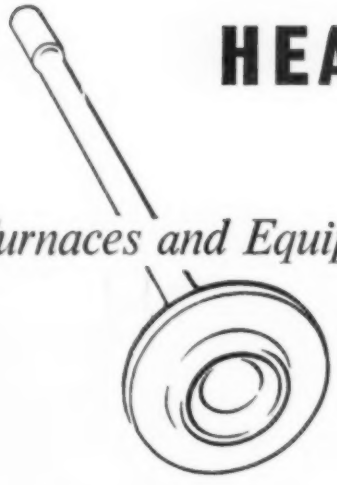

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METALLURGIA

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INCORPORATING THE METALLURGICAL ENGINEER

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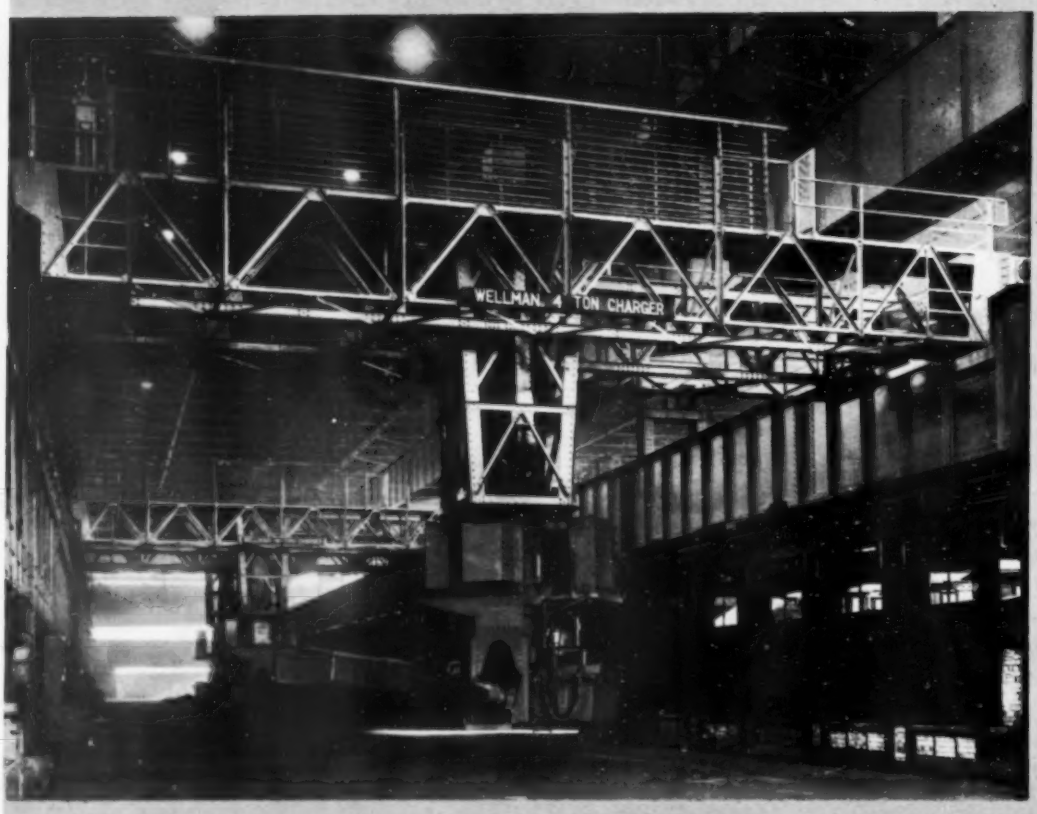

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

DECEMBER, 1957 Vol. LVI. No. 338

Railways and Steel

THROUGHOUT their history, the railways have been closely connected with the steel industry. On the one hand, the steelworks of the world depend on the railways for the transport of raw materials and finished products, and on the other, the railways depend on the steel industry for their materials of construction. In recent years, approximately 8·7% of total world consumption of steel (excluding the Chinese mainland) went directly or indirectly into railways. Of this, slightly more than half (4·4%) was in the form of rails and accessories; 0·9% in the form of tyres, wheels and axles; 0·5% in the form of other steel products used by railway administrations; and 2·9% in the form of other steel products used by the railway rolling-stock industry. Some 30% of this steel was consumed in Europe (excluding the U.S.S.R.), 37% in the U.S.S.R., and 21% in North America.

We take this opportunity of extending to Readers our Cordial Greetings for the Festive Season and Good Wishes for the Coming Year.

In view of the importance of the railway industry as a steel consumer, as indicated by these figures, the Steel Committee of the United Nations Economic Commission for Europe (E.C.E.) considered that an examination of the future trend of the demand for railway material and rolling-stock would be of value. On the basis of this study, the E.C.E. Secretariat have published a report* in the series in the economic aspects of trends in the production and consumption of important steel products. The preparation of the report has involved a study of different trends, some tending to raise and others to lower the demand for steel by the railways. As is pointed out in the introduction to the report, an investigation of this kind, prepared primarily within the content of steel demand, is bound to be tentative in character, since some of the issues arising are beyond the scope of such an inquiry. For instance the relationship between the railways and other forms of transport, particularly road transport, is part of a wider issue, as is the problem of priorities between various investment outlets. Nevertheless a number of general conclusions are drawn which are worthy of consideration.

It would appear that the demand for steel by the railways is likely in the coming years to remain at roughly the same level as at present, on the average, while continuing to account for a slowly declining proportion of total steel consumption. The world track length is remaining approximately constant, because the growth in developing countries is being counterbalanced by reductions made possible in some areas by improvements in operating methods, reduction of operations, and the closing down of unprofitable secondary lines. If anything, the trend as far as track materials is concerned may be towards a slow increase in demand, owing to the greater weight per unit length of the new rails and the fact that increasing loads and speeds accelerate replacement programmes.

In the same way, demand for steel for passenger coaches may remain more or less stationary, because the increased passenger traffic in regions undergoing increasing industrialisation may be largely offset by the sharp decrease in passenger traffic in North America and the better utilisation of stock in other areas. It is true that all-metal coaches are finding increasing use, but steel is not the only metal concerned. Although light alloys have, as yet, made only slight progress in this field, they constitute a factor which cannot be ignored. On the goods traffic side, despite the decrease in the weight of goods wagons relative to their carrying capacity, the increase in traffic in many countries points to the likelihood of a continuing expansion of demand for this purpose. In the traction field, the steam locomotive appears to be on the way out, and its increasing replacement by electric and diesel units points to a decline in demand.

The proportion of total demand satisfied by the traditional exporters of both railway material and rolling-stock seems likely to fall fairly steadily due to the fact that a number of countries which were previously importers are now producers. Thus, the export outlets of the major European producers are tending to contract, a serious matter for countries with a small domestic market.

The report goes on to suggest, from the point of view of both the steel industry and the rolling-stock manufacturers, that there are two broad lines of action which might be taken to ease the transition towards a relatively or absolutely declining market. The first is that, given the dispersal of much European productive capacity in a large number of small firms, a greater grouping of productive facilities would tend to encourage new investment and help the industry to meet competition from new producers on its traditional export markets.

The second point concerns the fact that demand for both permanent way material and rolling-stock has always been uneven from year to year. Due to financial considerations this unevenness will tend to be accentuated over the next decade or so, in the absence of some form of concerted action. It is particularly unfortunate that the perspective—at best—is one of demand at much the same level, with—for parts of the industry at least, particularly the old fashioned producers—a prospect of some contraction. Consequently, a concerted attempt to work out with a reasonable degree of accuracy the long-term demand for both permanent way and rolling-stock, followed by an attempt to phase the demand as far as possible over a period of time, would seem to be in the interests of both producers and consumers.

* "Railways and Steel," Geneva, 1957; 63 pp. including 34 tables and viii appendices. Obtainable in English (later French and Russian) from Sales Agents for U.N. publications. 4s. 6d.

Meeting Diary

2nd December

East Midlands Metallurgical Society. "Recent Developments in Plain Bearings," by M. J. Neale. College of Art, Green Lane, Derby. 7.30 p.m.

Institution of Production Engineers, Luton Section. "A New Approach to Quality Control," by Dr. R. M. Belbin. The Pink Room, Messrs. W. H. Allen, Sons & Co., Bedford. 7.30 p.m.

3rd December

Institute of Welding, Manchester and District Branch. "Oxygen in Steel Making," by J. L. Harrison. Reynolds Hall, College of Science and Technology, Manchester. 7.15 p.m.

Institution of Production Engineers, Coventry Graduate Section. "Centreless Grinding," by A. E. Adams. The Craven Arms Hotel, High Street, Coventry. 7.15 p.m.

Sheffield Metallurgical Association. "The Physical Chemistry of Chemical Analysis," by C. E. A. Shanahan. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

4th December

Incorporated Plant Engineers, Leicester Branch. "The Research, Information and Training Activities of P.E.R.A.," by D. D. Morgan. Bell Hotel, Leicester. 7 p.m.

Manchester Metallurgical Society. "The Metallurgical Applications of High Resolution Electron Microscopy," by Dr. J. Nutting. Manchester Room, The Central Library, Manchester. 6.30 p.m.

Powder Metallurgy Joint Group of the Iron and Steel Institute and the Institute of Metals. Inaugural Meeting. 10.30 a.m.—"Recent Developments in Powder Metallurgy," by Dr. I. Jenkins; 11.30 a.m.—"Developments in the Production and Quality of Metal Powders" (Presentation of short papers, followed by Discussion); 1.15 p.m.—Buffet lunch; 2.15 p.m.—"Developments in the Production and Quality of Metal Powders" (continued). Church House, Great Smith Street, London, S.W.1.

5th December

Institute of Metals. "Design and Operation of Waste Heat Boilers in the Chemical Industry," by Capt. W. Gregson. Joint Meeting with the **Chemical Engineering Group of the Society of Chemical Industry.** Chemical Dept., The University, Woodlands Road, Bristol. 6.30 p.m.

Institution of Production Engineers, London Section. "Recent Developments in Plastics Moulding Techniques," by E. R. Martin. Powers-Samas Accounting Machines, Ltd., Aurelia Road, Croydon, Surrey. 7.15 p.m.

Institution of Production Engineers, Reading Section. "Ultrasonic Machining," by a Representative of Mullard, Ltd. The Great Western Hotel, Reading. 7.30 p.m.

Leeds Metallurgical Society. "Some Uncommon Failures of Engineering Plant in Service," by G. A. Cottell. Lecture Room C, Chemistry Wing, The University, Leeds, 2. 7.15 p.m.

6th December

Institute of Physics Non-Destructive Testing Group. "Structural Imperfections in Metals and their effect on Mechanical Properties," by Prof. N. F. Mott, F.R.S. 47, Belgrave Square, London, S.W.1. 5.30 p.m.

9th December

Institute of Metals, Scottish Local Section. "Recent Developments in Magnesium-Base Alloys," by Dr. E. F. Emley. Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2. 6.30 p.m.

9th–10th December

Institute of Metals. "Symposium on Vacancies and other Point Defects in Metals and Alloys," arranged by the Metals Physics Committee. Atomic Energy Research Establishment, Harwell. Attendance by advance registration only.

10th December

Institute of Metals, South Wales Local Section. "Hardness of Metals," by Dr. D. Tabor. Department of Metallurgy, University College, Singleton Park, Swansea. 6.30 p.m.

Institute of Physics' Electronics Group. "Infra-red and Microwave Modulators using Free Carriers in Germanium," by Dr. A. F. Gibson. 47, Belgrave Square, London, S.W.1. 5.30 p.m.

Sheffield Metallurgical Association. "Some Everyday Refractory Problems," by Dr. P. W. Clark. B.I.S.R.A., Hoyle Street, Sheffield. 7. p.m.

11th December

Institute of Metals, London Local Section. "Properties of Castings," by F. Hudson. Joint Meeting with the London Branch of the Institute of British Foundrymen. Constitutional Club, Northumberland Avenue, London. 7.30 p.m.

North East Metallurgical Society. "Stress-Corrosion Cracking," by Dr. T. P. Hoar. Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough. 7.15 p.m.

12th December

Incorporated Plant Engineers, Glasgow Branch. "Electric Arc Welding," by Dr. J. W. Macfarlane. Scottish Building Centre, 425/427, Sauchiehall Street, Glasgow. 7.15 p.m.

Institute of British Foundrymen, Beds. and Herts. Section. "S.-G. Iron—A Versatile Engineering Metal," by W. W. Braidwood. Assembly Room, The Town Hall, Luton. 7.30 p.m.

Liverpool Metallurgical Society. Joint Meeting with the **Institute of Metals.** "Titanium," by Dr. J. W. Rodgers. Liverpool Engineering Society, 9, The Temple, Dale Street, Liverpool. 7 p.m.

Southampton Metallurgical Society. "Creep," by E. A. G. Liddiard. Southampton University. 7.15 p.m.

13th December

Institute of Metal Finishing, Organic Finishing Group. "Choice of Phosphate Pre-Treatments," by R. F. Drysdale. Royal Society of Tropical Medicine and Hygiene, 26, Portland Place, London, W.1. 6.30 p.m.

Institute of Physics, Manchester and District Branch. "The Strength of Materials with special reference to Metals," by Dr. A. H. Cottrell, F.R.S. The Bragg Lecture Theatre, Manchester University. 6.45 p.m.

Institution of Mechanical Engineers. James Clayton Lecture: "Hydrostatic Machines," by Prof. Dr. Ing. Hans Thoma. 1, Birdcage Walk, Westminster, London, S.W.1. 6 p.m.

16th December

Institution of Structural Engineers. Lancashire and Cheshire Branch. "A Review of Structural Steel Work in the 'Seraphim' Extensions at Appleby-Frodingham," by S. Richards and N. Lancaster. College of Science and Technology, Manchester. 6.30 p.m.

17th December

Institute of British Foundrymen, East Anglian Section. Film Evening—"Flow of Metal into Moulds," "The First Four Years," and "Bubble Model of a Metal Structure." Lecture Hall, Public Library, Ipswich. 7.30 p.m.

18th December

Society of Chemical Industry, Corrosion Group. Teaching Corrosion Science: "Existing Facilities," by L. W. Stubbs; and "Future Requirements," by T. P. Hoar. 14, Belgrave Square, London, S.W.1. 2.30 p.m.

20th December

West of Scotland Iron and Steel Institute. "Electric Melting Furnaces," by F. S. Leigh. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

Aeroweb Honeycomb Core

Aero Research, Ltd., honeycomb will, in future, be marketed under the registered trade name of Aeroweb. Aeroweb metal honeycomb core is used in conjunction with Redux adhesive in film form for the production of sandwich panels for aircraft, boats, motor vehicles and other industrial applications where a high strength/weight ratio is required. It is suitable for flat surfaces of constant or tapering thickness, as well as for shapes involving single or double curvature. Aeroweb honeycomb is supplied in thicknesses up to 9 in. in cell sizes of $\frac{1}{8}$ in., $\frac{1}{4}$ in., and $\frac{3}{8}$ in. inscribed circle, and in various foil thicknesses.

The Direct Chloride Process For Tinning Cast Iron

By C. J. Thwaites, M.Sc., A.R.S.M., A.I.M.,* and J. J. Day†

The newly developed direct chloride process for hot-tinning cast iron gives adequate adhesion to whitemetal bearing alloys, provided that fine grit is used for shot blasting and an ebullient flux layer covers the first tinning bath. The author discusses the influence of the composition and structure of the cast iron, the preliminary surface treatment, and the tinning and whitemetalling conditions.

A NEW technique for hot-tinning cast iron has recently been developed in the laboratories of the Tin Research Institute. This new technique is the outcome of modifications to the original Fused Chloride method,[1] which was sometimes found to be inconvenient, since it involved a precisely timed fused-salt treatment prior to dipping in the molten tin bath. Later work showed that, provided a particular mechanical preparation of the iron was correctly and carefully carried out, and that an especially active flux layer was maintained on the tin bath, the separate salt bath treatment could be eliminated. The new technique, which is considered to provide generally better coatings than the older procedure, has been called the "Direct Chloride" method, and working instructions have already been published.[2, 3]

Experimental Procedure

Any casting scale, sand or slag may be initially removed from the surface of the cast iron by normal mechanical cleaning methods, and any heavy grease by trichlorethylene treatment. The iron is then shot-blasted with a 70 mesh, angular, chilled-iron grit until all surfaces present a dull, grey, matt finish. It is recommended that 30 to 60 seconds of shot-blasting time is given to every square inch of surface, excessive time not being detrimental. In all the experiments carried out at the Institute, a compressed air (80 lb./sq. in.) type, hand-operated shot-blast cabinet was employed.

Provided the shot-blasted surface is not subsequently contaminated by grease or finger-marking, no degreasing is required. Before tinning, the piece is now dipped in an aqueous flux solution containing

Zinc chloride	24 lb.
Sodium chloride	6 lb.
Ammonium chloride	3 lb.
Hydrochloric acid	½–1 pint
Water to make	10 gal.

In the case of large castings, preheating before tinning is not desirable and, indeed, is considered to be generally unnecessary. However, heating to 200° C. after grit-blasting may be carried out, provided that flux solution is brushed on to the prepared surface immediately before entering the first tin bath. Alternatively, the heated piece is given a final short shot-blast treatment to remove oxide. It may then be directly lowered into the ebullient flux cover on the tin bath without aqueous pre-fluxing. Aqueous fluxing of the prepared surface prior to preheating is detrimental and prevents satisfactory tinning.

* Assistant Chief Metallurgist, Tin Research Institute.
† Research Officer, Tin Research Institute.

Fig. 1.—Spraying water on to the flux blanket to cause ebullience.

The first or rough-tinning bath is covered with a flux blanket which, when anhydrous, may be only ½ in. thick. The preferred composition is the same as the solid constituents of the flux solution mentioned above. Prior to immersion of the prepared articles into the tinning bath, water is dripped or sprayed on the flux until a frothing layer 2 or 3 in. thick is obtained. This operation is shown in Fig. 1. The cast iron is lowered slowly through the ebullient flux layer into the tin (Fig. 2) which is held at 300–320° C. After immersion for at least 3 minutes, the piece is removed and transferred to a second or "fine" tinning bath at 250° C., normally covered with a tinning oil. After immersion for a similar time, it is then removed and allowed to cool, or is quenched as required.

Cast iron is frequently employed for the manufacture of bearing shells, and it was thus desirable to examine the effect on the adhesion of the bearing alloy to the cast iron shell of varying the conditions in tinning by the Direct Chloride process, and in the subsequent white metalling operation.

Samples of various irons were prepared and tinned under different conditions, and subsequently white-metalled. Except where stated, a bearing metal containing 7% antimony and 3·5% copper was used, which was cast from the recommended temperature of 370° C.[4] on

Fig. 2.—Immersing a large grey iron bearing shell into the flux-covered tinning bath.

to the tinned iron, reheated to 250° C. This whitemetalling procedure is called subsequently the "standard" lining method. Other bearing alloys were also cast-on to examine the effect of whitemetal composition on adhesion. In most cases "puddling" was employed to dislodge any entrapped oxide or gas bubbles; cooling was generally carried out by spraying water on to the underside of the iron to ensure directional solidification from the bond.

The method of testing the bond strength between the bearing alloy and the iron was essentially that due to Chalmers,[3] but with an improved jig to ensure axial application of the load (Fig. 3). A disc of the bearing metal is isolated by trepanning an annular groove from the outer face of the alloy down to the iron surface. A flat-bottomed hole of diameter less than the internal bore of the annulus is then drilled through the iron from the opposite face. The load required to break the disc of whitemetal from the iron is measured, the resultant bond strength being expressed as a stress in tons/sq. in. The relevant dimensions of the present test-pieces are shown in Fig. 4, giving a test area of about 0·25 sq. in. Each bond strength value quoted is a mean of not less than three individual tests.

Separate samples of each type of iron were prepared for each series of tests.

TABLE I.—TYPES OF CAST IRON USED IN THE EXPERIMENTS.

Code Number	Type	Cast Section Thickness	Type of Graphitic Carbon
1	Grey	½ in.	Fine flake
2	S.G.	½ in.	Nodular
3	S.G.	½ in.	Nodular
4	Meehanite	½ in.	Fine flake
5	Grey	½ in.	Medium flake
6	Grey	½ in.	Coarse flake
7	S.G.	½ in.	Nodular
8	Grey	½ in.	Very fine (undercooled)
9	Grey	½ in.	Very coarse flake

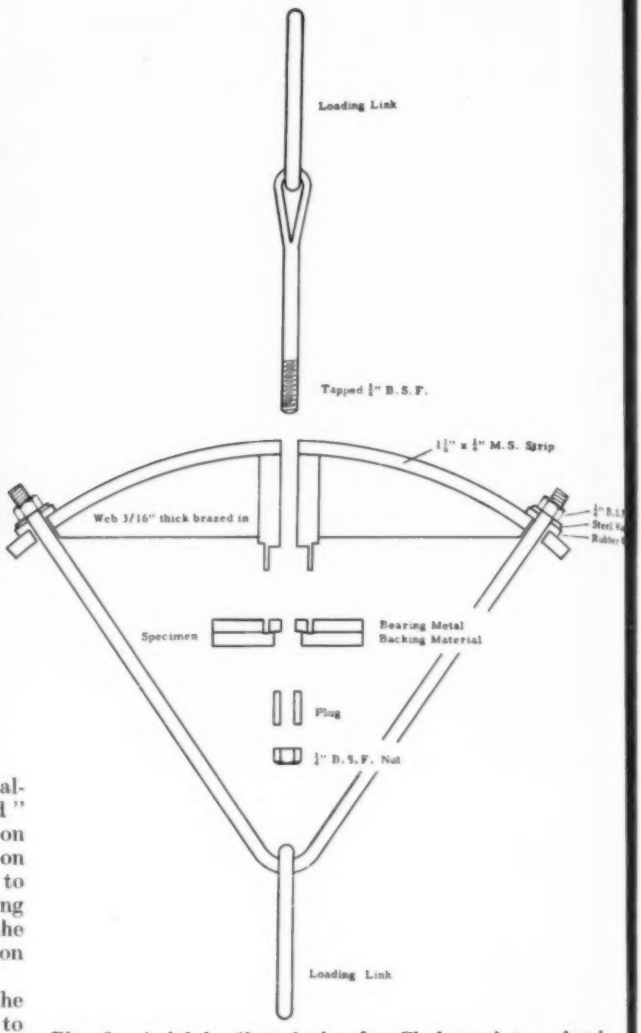

Fig. 3.—Axial loading device for Chalmers' type bond strength tests.

Experimental Results

Effect of Type of Cast Iron

Nine different types of iron were used. The coding and a brief description of these materials—all being normal production irons in use commercially, and each deriving from a different foundry—is given in Table I.

The majority of the experiments were carried out using the as-cast surface of the iron, that is to say, without any prior machining or grinding. The samples, with the exception of No. 9, were tinned and lined under the standard conditions given above. Iron No. 9 was lined

TABLE II.—BOND STRENGTHS WITH DIFFERENT CAST IRONS.

Iron Number	Bond Strength (tons/sq. in.)
1	2·5
2	3·6
3	3·4
4	3·2
5	2·6
6	2·4
7	3·6
8	2·2
9	2·0*

* All samples except No. 9 whitemetalled with tin-base alloy. No. 9 with lead-base alloy.

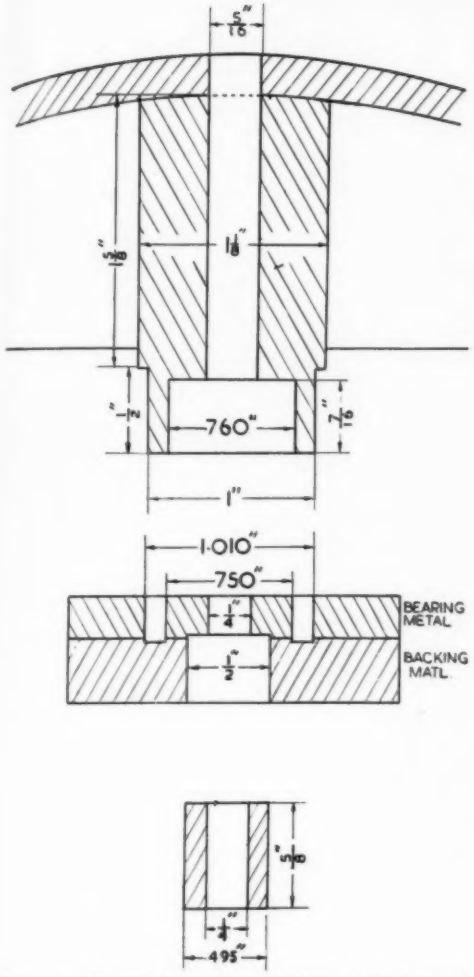

Fig. 4.—Dimensions of machined test-piece for bond strength tests.

with a lead-base alloy for a specific purpose. Adhesion tests were carried out and the results obtained are given in Table II.

It will be evident that spheroidal graphitic or Meehanite type irons give rather better adhesion figures than common grey iron. There is no significant difference in adhesion, however, between the grey irons from different sources, indicating that the Direct Chloride process is not especially sensitive to alterations in metallurgical structure.

Effect of Mechanical Preparation

In criticism of the direct chloride process, it was suggested that a 70 mesh grit for shot-blasting was excessively fine and gave uneconomic losses of the grit. The suitability of coarser grades of grit was therefore examined. Both 30 and 50 mesh grits gave tin coatings of satisfactory appearance, whereas on a surface prepared with 16 mesh material, the tin coating completely dewetted (Fig. 5). Bond strength values after preparing iron samples with both 30 and 70 mesh grits, using the standard tinning and lining procedures, are given in Table III, from which it will be seen that the coarser material gives significantly inferior results.

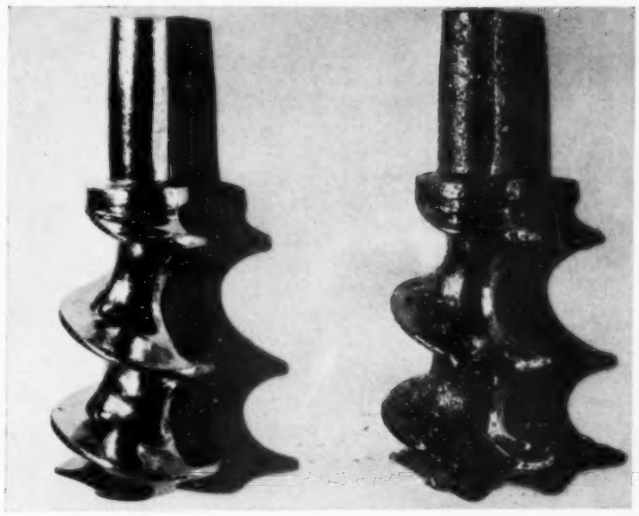

Fig. 5.—Effect of grit size during shot-blasting : left—70 mesh grit resulted in perfect tinning ; right—16 mesh grit resulted in almost complete dewetting.

It is interesting to note that a surface prepared with 30 mesh grit and tinned appeared to be "porous," and during remelting of the tin prior to whitemetalling, gas bubbles appeared under the molten tin layer. Poor adhesion was obtained with some of the samples, and examination of the fracture surface of the broken test-pieces showed that some gas cavities remained when the whitemetal was cast onto the iron. A typically poor bond with gas cavities is shown in Fig. 6*a*. The difference in appearance of the fractured bonds on samples tinned after preparation with 30 and 70 mesh grits, respectively, is shown in Figs. 6*b* and 6*c*.

Two other types of mechanical preparation were given study, namely, vapour-blasting and grinding ; with a 50 micron alumina abrasive, the former type of pre-treatment gave a bond strength value of 1·5 tons/sq. in., but there appeared to be a tendency for more scatter in the individual results. A ground finish produced with a clean Carborundum wheel tinned as readily as the fine shot-blasted surface, and a mean bond strength value of about 2·3 tons/sq. in. was obtained for each of the three types of iron represented by Nos. 4, 5 and 7. A typical fractured bond on a ground surface is shown in Fig. 6*d*.

In tests on the No. 9 iron, no difference in adhesion was obtained between an as-cast surface and one treated with a coarse shot in a Wheelabrator machine when each was subsequently treated with 70 mesh grit in the prescribed manner.

It should also be noted that cast iron prepared for tinning by machining alone, or by pickling, resulted in unsatisfactory tin coatings being obtained, as was the case when a very coarse shot-blast treatment was given (Fig. 5). Casting whitemetal on to such a tinned surface

TABLE III.—EFFECT OF GRIT SIZE.

Iron Number	Bond Strength (tons/sq. in.) using	
	30 Mesh Grit	70 Mesh Grit
4	1·9	2·7
5	1·5	2·3
7	2·9	3·5

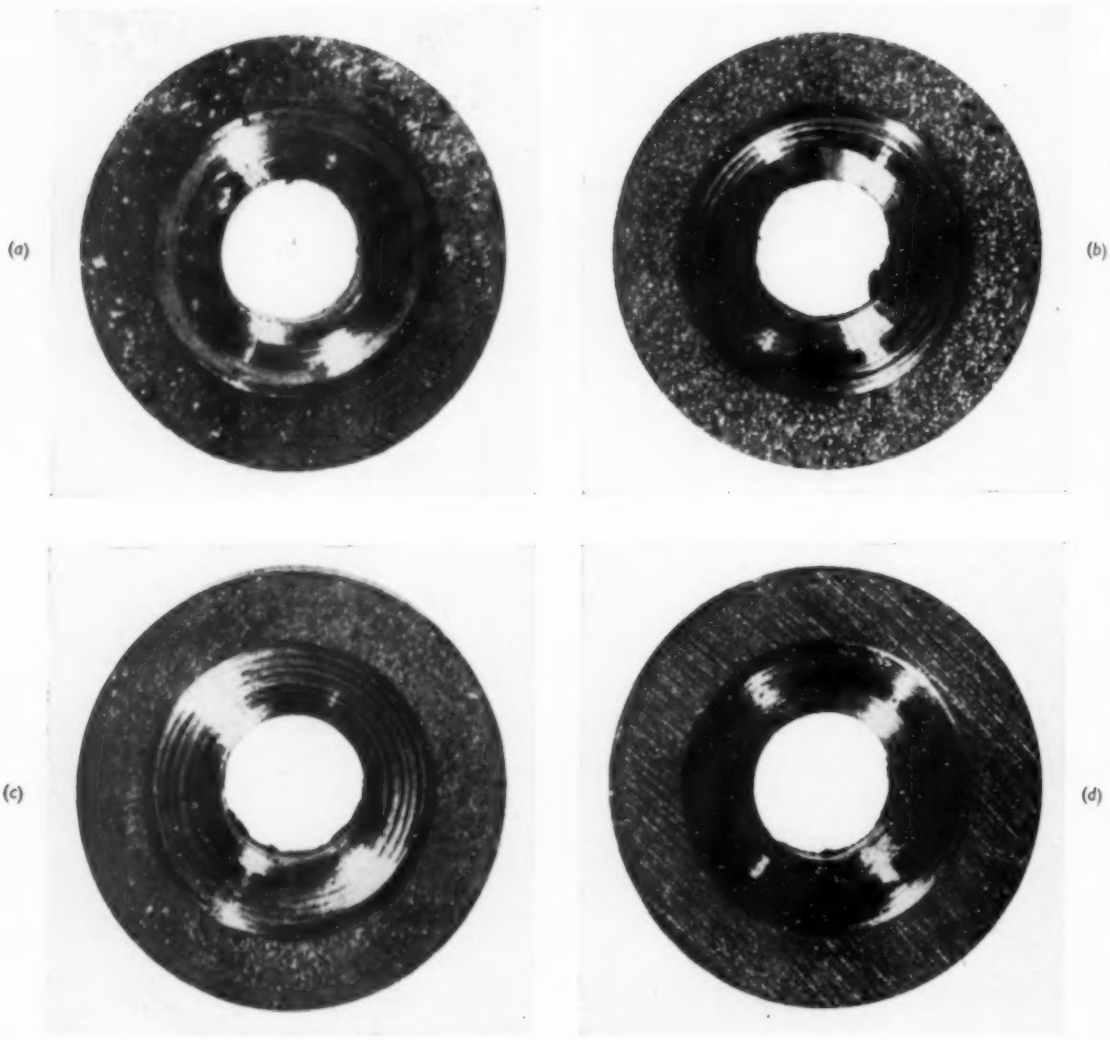

Fig. 6.—Appearance of fractured bond surfaces after Chalmers' tests: (a) gas cavities at interface, giving poor bond strength on surface prepared with 30 mesh grit; (b) perfect bond on surface prepared with 30 mesh grit; (c) perfect bond on surface prepared with 70 mesh grit; (d) perfect bond on surface prepared by grinding.

generally resulted in low bond strength values in the range 0–1·0 tons/sq. in.

Effect of Tinning Conditions

Tinning with Tin-Lead Alloy

It is sometimes common practice to pre-tin bearing shells with a tin-lead alloy, particularly if a lead-base bearing metal is to be cast-on. Samples of the No. 5 grey iron were prepared by the standard method and single-pot tinned in a bath of a 50% tin, 50% lead alloy, using the ebullient flux cover. Two different bath temperatures were employed with the standard whitemetalling procedure. The mean bond strength values obtained were 1·8 and 2·1 tons/sq. in. when the tinning bath temperatures were 250° and 350° C., respectively. These figures may be compared with those obtained on samples pre-tinned with pure tin and shown in Tables II and III. It is believed that the slightly lower adhesion obtained at the lower dipping temperature is a significant effect. It was, however, found that the effect of grit size on bond strength was more pronounced with the tin-lead alloy coating, a 30 mesh grit giving mean values as low as 0·8 and 1·3 tons/sq. in. for tinning bath temperatures of 250° and 350° C., respectively. At the lower temperature it was found to be difficult to obtain adhesion, and no bond was obtained in several instances. Thus, only if the recommended tinning bath temperature is used can pre-tinning be satisfactorily carried out in a 50/50 tin-lead alloy.

Effect of Tinning Temperature

To examine further the effect of dipping temperature on adhesion, samples were tinned in pure tin in the standard manner, the first bath being at 310° C. They were then transferred to an intermediate bath held at any desired temperature. After the prescribed period of immersion they were then dipped in the final oil-covered bath at 250° C. An immersion time of 3 minutes was

allowed in each bath. This triple procedure was necessary because the temperature of the flux-covered bath could not exceed 320° C. without detrimental effects on the flux cover. The final dip at a low temperature was required to retain a satisfactory thickness of tin coating suitable for subsequent re-heating and whitemetalling. No difference in the adhesion was found when the intermediate bath temperature was varied between 250° and 450° C. Metallographic examination of these samples showed little or no difference in appearance between the layers of tin-iron compound, this correlating with the experimental results obtained.

Effect of Tinning Time

An attempt was made to vary the thickness of the tin-iron compound layer by immersing samples for different times in the tinning bath at the normal dipping temperature. With No. 8 grey iron, similar adhesion was obtained on samples dipped for 1, 3 and 10 minutes, but there was an increase of about 30% in the bond strength values with an immersion time of 30 minutes. With No. 9 iron, there was no similar effect of the time of immersion.

The known desirability of prolonged immersion in the tinning baths is thus not very evident from the bond strength figures, but it should be borne in mind that increased times will give more chance for the tin to enter casting cavities and dislodge any entrapped flux, resulting in a more continuous tin coating and, hence, improved bonding to the bearing alloy.

Effect of Whitemetalling Conditions

Whitemetal Composition

Apart from the standard 7% antimony plus 3·5% copper alloy, three other whitemetals were used. The compositions of these alloys are shown in Table IV. Initial preparation, tinning, and reheating procedures for the samples were standard. The whitemetal alloys were cast-on in the normal way at the recommended temperatures (also given in Table IV). Bond strength values obtained on these samples are given in Table V.

It is clear that, although the tin-base bearing metal A results in the best adhesion, there is a definite trend towards lower bond strengths as the tin content is decreased, and wherever it is economic and practicable, the high-tin bearing alloys are to be preferred.

Rate of Cooling

Samples of No. 8 iron were tinned and whitemetalled by the standard procedure and either allowed to cool freely in the air or, alternatively, water-quenched with sprays from the underside of the pieces, using two different rates of spraying. There was no significant difference in the bond strengths obtained by the various methods of cooling. This is contrary to the findings of Forrester,[4] whose experiments, however, were with steel bearing shells, and not cast iron. It is possible that the lower thermal conductivity and greater thickness of the iron prevented rapid solidification by quenching.

TABLE IV.—WHITEMETAL ALLOY COMPOSITIONS.

Whitemetal Code	Sn (%)	Pb (%)	Sb (%)	Cu (%)	Ni (%)	Casting Temperature (° C.)
A	Bal.	—	7	3·5	—	370
B	10	Bal.	15	1	1–2	500
C	15	Bal.	15	0·2	—	450
D	12	Bal.	12	0·5	—	450

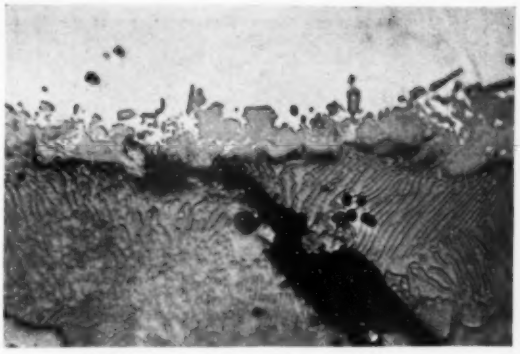

Fig. 7.—Apparent bridging over of coarse flake graphite by tin and $FeSn_2$ layers. Normal section. × 1,500

Reheating Temperature

A few samples of No. 8 iron were tinned in the normal manner and then reheated to 350° C., instead of the standard 250° C., prior to casting-on the whitemetal. The bond strength so obtained was 2·3 tons/sq. in., showing an increase over the value of 1·7 tons/sq. in. obtained on standard samples prepared and tested at the same time. The latter figure is somewhat below the normally expected value on this iron shown in Tables II and V.

This evidence, therefore, of improved adhesion with higher reheating temperature is open to some suspicion. At the very least, however, it may be said that there is no apparent detrimental effect in altering the reheating temperature within the range 250° to 350° C., provided that undue oxidation of the tin coating is avoided.

Theoretical Considerations

In the earlier work on the Fused Chloride process, Cresswell[1] showed that the graphite flakes in grey cast iron appeared to be bridged over by the tin coating and by the underlying layer of tin-iron intermetallic compound, $FeSn_2$. A similar phenomenon was found in iron prepared by the Direct Chloride process, and is shown by the photomicrograph of a normal cross-section in Fig. 7. It was thought that tinning was facilitated by erosion of surface graphite during the fine grit-blasting treatment, in conjunction with flowing of the adjacent ferrite over the " cavity " thus formed. A surface consisting largely of ferrite and pearlite would then be presented to the molten tin. This hypothesis was proposed in the light of evidence that only surfaces treated with suitably fine grits, e.g., 70 mesh, will tin satisfactorily, whereas those shot-blasted with coarse grits or only fine-machined produce a completely dewetted tin coating.

Examination under the microscope, at the highest possible magnification, of normal cross-sections of

TABLE V.—EFFECT OF WHITEMETAL COMPOSITION ON BOND STRENGTH.

Iron Number	Bond Strength (tons/sq. in.) with Whitemetal			
	A	B	C	D
1	2·5	1·6	2·2	—
2	3·6	1·7	2·3	—
3	3·4	2·0	2·5	—
4	3·2	2·2	2·4	—
5	2·6	1·5	2·4	—
6	2·4	2·0	2·2	—
7	3·6	2·2	2·9	—
8	2·2	—	—	—
9	—	—	—	2·0

Fig. 8.—Fine machined surface. Taper section (10 : 1). × 150

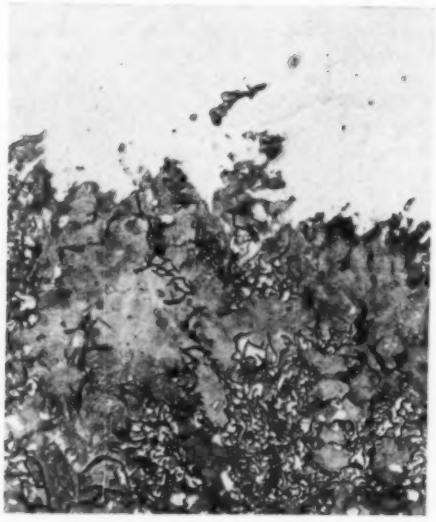

Fig. 9.—Fine machined surface subsequently shot-blasted with 70 mesh angular iron grit. Taper section (10 : 1). ×150

samples did not reveal the differences between these surface conditions, and the taper-section technique[6] was therefore employed. Samples were mounted at an angle of 6° to the surface to be polished, to give a linear magnification normal to the tin-iron interface 10 times greater than that parallel to the interface, thus facilitating examination of the extreme surface layers. Figs. 8–12 are all photomicrographs of taper sections having distortion ratios of 10 : 1. The magnifications quoted in these figures are those obtained optically.

Figs. 8 and 9 show, respectively, at a low magnification, the appearance of a fine-machined surface and one treated subsequently with 70 mesh grit. Considerable alteration in the surface contour is evident, indicating severe deformation of the metal surface. On hot-tinning the first of these samples, a fully dewetted coating was obtained which, when examined at a higher magnification, had the appearance shown in Figs. 10 and 11. It may be observed from these photomicrographs and Fig. 8 that during machining the cellular networks of graphite have been intersected, leaving considerable graphite exposed at the surface. By the mechanism of machining, metal particles are broken off by compressive forces and, in the case of cast iron, fracture will occur along the weak planes of the graphite flakes. Thus, there is every chance of obtaining a relatively high proportion of carbon on the surface, although only a little general smearing was evident. The latter fact is confirmed by the formation of a substantially continuous layer of $FeSn_2$ on such surfaces, which would not be present were there an interfering carbon smear. This alloy layer aids retention of traces of tin during dipping, as is clearly seen in Figs. 10 and 11 ; this entrapped tin confers the typical " satin " appearance to the iron surface from which the tin coating has dewetted.

Shot-blasting with 70 mesh grit must initially remove any loosely adhering flakes of carbon on the machined surface. Severe deformation of the outer layers of the

Fig. 10.—Discontinuous tin coating retained on machined cast-iron surface. Taper section (10 : 1). × 600

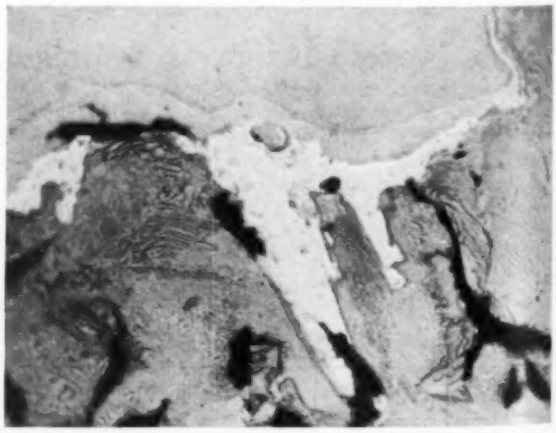

Fig. 11.—Entrapped tin and surface graphite on machined cast iron surface. Taper section (10 : 1). × 1,200

metal follows, and the majority of the graphite flakes near the surface appear to be disintegrated and dispersed, leaving a ferritic structure. Fig. 12 shows that flakes originally intersecting the machined surface of the iron are now some distance below the shot-blasted surface and are overlaid by a band of heavily deformed material. The tin coating is continuous over the region. The severity of the surface deformation was readily shown in a sample of low-carbon steel shot-blasted in the same manner (Fig. 13). This photograph shows the "laminated" effect produced by compressing the surface. A taper-section on this sample indicated that the approximate depth of working caused by the fine grit-blasting was 0·002 in.

The use of a coarse shot-blasting grit was seen to have caused extreme roughness, and to have removed large particles from the machined surface. Nevertheless, the severe surface working obtained with the fine grit was not present. As a result, there was no significant reduction in the amount of graphite exposed at the surface.

Thus, the original hypothesis was to a large extent substantiated, the major factor being the flowing and distortion of the metal surface. The erosion effect originally suggested was not found to occur with individual graphite flakes, but in certain thin sections of cast iron whole colonies of fine, undercooled graphite at the surface were disintegrated and completely removed, leaving cavities of considerable size.

In using the Direct Chloride process, a dipping time of 1 or 2 minutes elapses before the iron retains a satisfactory tin coating, and a minimum dip of 3 minutes is recommended. This was at first thought to be due to the period required to raise the iron surface to sufficient temperature for reaction with the molten tin to take place. However, cast iron electroplated with thin copper or nickel layers, both being easily tinnable metals, tinned in about one quarter of this period. and it was concluded that some surface changes must take place in this initial immersion period. Microscopic examination did not reveal this change, but it was considered likely that it was associated with the few graphite discontinuities at the iron surface remaining after fine shot-blasting, one such flake being visible in Fig. 12. If the unwetted areas are large in relation to the thickness of the molten tin layer, a break will appear in the coating.[7] If, however, the holes in the $FeSn_2$ caused by these residual graphite outcrops gradually become closed by lateral growth of the layer, the tin coating will then become a continuous film.

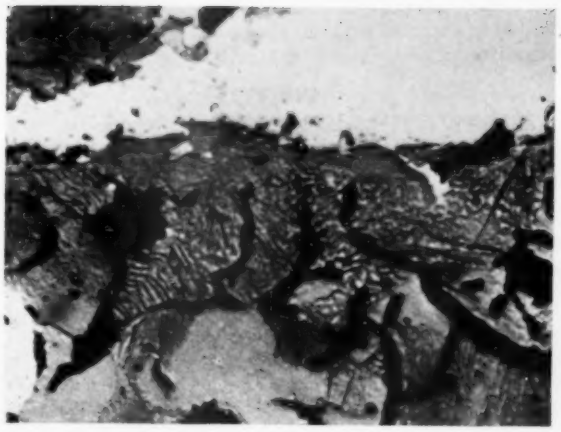

Fig. 12.—Graphite flakes overlaid by deformed ferrite after fine shot-blasting. Taper section (10 : 1). × 2,000

An alternative explanation of the initial delay before tinning, lies in the probable lower rate of reaction of tin with iron containing the amounts of incidental impurities normally present in ordinary cast iron. One of the major elements is phosphorus, which is present as a eutectic of iron and iron phosphide. Careful micro-examination indicated that, after tinning, the layer of $FeSn_2$ on these areas generally appeared to be thinner and less continuous when compared with that formed on ferrite (Fig. 14). This confirms the lower reaction rate on the phosphide phase and, consequently, the "incubation" period before these areas are wetted by the tin. It is likely, therefore, that the initial immersion period, prior to a continuous tin coating being retained, is a result of two simultaneous factors, namely the growth of the $FeSn_2$ layer over both the residual graphite inclusions and the phosphorus-rich regions in the surface. The experimental evidence indicates a trend towards improved bond strength values with increased temperature or time during tinning and whitemetalling. The gradual bridging over of the residual graphite flakes by growth of the $FeSn_2$ layer is not considered likely to affect adhesion significantly, but higher bond strength values would certainly be expected

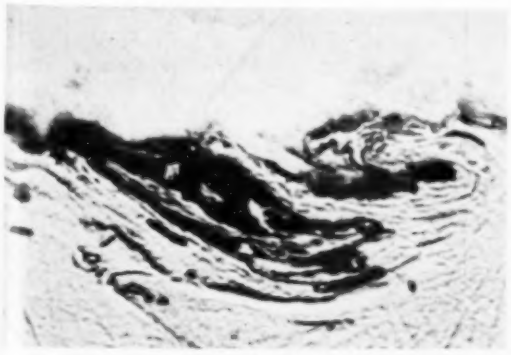

Fig. 13.—Severely deformed surface regions caused by fine shot-blasting a low carbon steel. Normal section. × 2,500

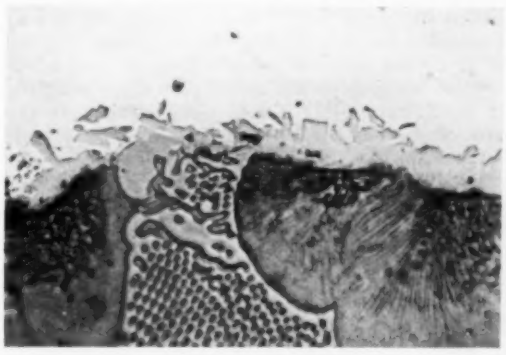

Fig. 14.—Comparison between thickness of $FeSn_2$ layers on ferritic and on phosphide eutectic areas. Normal section. × 1,000

by the formation of a more continuous $FeSn_2$ bond on the phosphide eutectic regions, particularly as a significant proportion of this phase is exposed at the surface.

Summary

The newly developed Direct Chloride process for hot-tinning cast iron has been shown to give adequate adhesion to whitemetal bearing alloys. The adhesion is greatest with spheroidal graphitic irons and when tin-rich whitemetals are cast-on. Provided that 70 mesh fine angular grit is employed for the preliminary mechanical preparation, and that the recommended ebullient flux layer is used on the first tinning bath, variations in iron composition and in tinning and whitemetalling conditions have little influence on adhesion.

Detailed metallographic examination showed that the graphite flakes outcropping at the iron surface are crushed and removed by the severe surface deformation during shot-blasting. The recommended 3 minutes minimum immersion time in the first tinning bath appears to be necessary to allow time for a continuous $FeSn_2$ layer to form on the slower reacting phosphide eutectic exposed at the surface, and over the outcrops of remaining graphite.

Acknowledgments

This investigation was carried out in the laboratories of the Tin Research Institute, and the authors are indebted to the International Tin Research Council for permission to publish this paper. Appreciation of experimental work by Mr. B. Eyre and Miss N. Young must also be expressed.

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Research into Ceramic Tools at PERA

CERAMIC cutting materials have very high resistance to abrasive wear, even at high temperatures. Under favourable circumstances, ceramic tools have been used at speeds many times higher than can be achieved with conventional cutting tools. For example, cast iron has been machined at a speed of nearly 1,000 ft./min., and steel at a speed of over 1,100 ft./min. An additional advantage is that the principal constituent of ceramic tools is aluminium oxide, which is obtainable from freely available raw materials. Ceramic cutting tools are, however, in their early stage of development, and a number of technical problems will have to be solved before the full possibilities of this type of tool are realized in industry generally.

Six Types on Test

The Production Engineering Research Association (PERA) is at present investigating at its Melton Mowbray headquarters the performance of six types of ceramic tool on behalf of the Ministry of Supply. For purposes of comparison similar tests are being carried out on cemented carbide tools. Special equipment required for the investigation has been made, and preliminary tests are also being carried out to establish the ranges of cutting conditions to be employed, and to determine the wear characteristics of various ceramic materials.

The performance of the tools will be determined over a range of cutting speeds and feeds when rough and finish machining alloy steel. Performance will be assessed on the basis of tool wear in roughing operations and of workpiece surface finish in finishing operations. The machining experiments will be performed on a 17 in. swing high-speed centre lathe with built-in running centre and variable speed range. As vibration has a particularly destructive effect on the performance of ceramic tools, special attention is being given to the vibration characteristics of the machine tool and tooling generally.

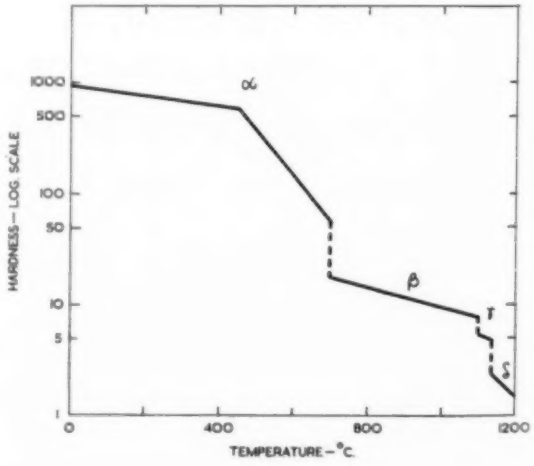
Economic Aspects

An examination will also be made of some economic aspects of the use of ceramic tools by carrying out tests in which the effects of various feed and speed combinations giving constant rates of metal removal will be explored. These tests will indicate the most suitable combinations of feed and speed for specified rates of production. The effects of cutting speeds of up to 1,600 ft./min. and feed rates of up to 0·030 in./rev. will be investigated during the tests. Samples of chips will be examined to determine the effects of cutting speed and feed rate on the ratio of deformed to undeformed chip thickness.

Correction

HARDNESS AND OTHER PHYSICAL PROPERTIES OF METALS IN RELATION TO TEMPERATURE

We regret that an error appeared in the article by Mr. E. R. Petty which was published in our November issue. In Fig. 2 on page 233 the positions of the 1,000 and 500 marks on the " Hardness—Log. Scale " ordinate were wrong. The correct graph is shown here.



Powder Metallurgy

Technique and Applications

Articles have been made from metal powders from the earliest times, but only during the present century has there been a technological approach to powder metallurgy. In this account of a lecture given by Dr. Ivor Jenkins, Chief Metallurgist, The General Electric Co., Ltd., to the recent Conference of the Purchasing Officers' Association, reference is made to the production and testing of metal powders and the manufacture of articles from them by compaction and sintering. Included in the applications mentioned are a number of engineering components which could not be made by conventional metallurgical techniques.

THE term powder metallurgy may be considered as including the manufacture of metals in the form of powder and the conversion of the powder into ingots or finished shapes by the application of pressure and heat, so that the metal particles bond together below the melting point of the major constituent to form a coherent solid mass. The powder can be that of a metal, an alloy, an intermetallic compound, or even a non-metallic substance, and, of course, mixtures of any of these. Powder metallurgy, therefore, provides a means of producing simple and complex components without the use of conventional melting and casting processes, and often without having to resort to working processes and fabrication techniques.

The basic stages in the manufacturing process include the preparation of the metal powder, which is then introduced into a metal mould of the required form and pressed at a pressure of several tons to the square inch. During this operation the metal powder deforms and, largely by a process of mechanical interlocking of the particles, a coherent pressing is produced which, with reasonable care, can be handled. The body is then furnace heated in either a vacuum or an atmosphere, the composition of which is controlled to ensure that oxidation or any other undesirable reaction does not occur. During this process the metal powder particles sinter together ; the voids which have not yet been eliminated by the initial compaction of the powder are reduced in volume and in some cases completely eliminated, and the whole of the compact shrinks

The choice of sintering conditions is determined by the nature of the metal handled, and by the properties required in the final product Where high density and good mechanical properties are required, it is necessary to produce a sintered body as free as possible from internal porosity For pure metals this involves sintering at a temperature close to the melting point, e.g. copper (melting point 1,083° C.) is sintered at about 900° C. ; iron (1,535° C.) is sintered at 1,350° C. ; tungsten (3,380° C.) at 3,100° C. If an alloy consists of metals of widely different melting points, a mixture of powders of both metals may be sintered above the melting point of one but below that of the second metal. This so-called "liquid phase" sintering accelerates the sintering process considerably, the molten phase enveloping the powder particles of the second metal, expelling the air or gas in the cavities between the particles and alloying with them to produce a very dense product. Alternatively, the higher melting point material may be sintered first to produce a coherent sponge-like body, which is then brought into contact with the second metal which is molten. The latter will then be absorbed into the pores of the first, just as blotting paper soaks up ink. This process is known as "infiltration." Both of these processes can be used to make mixtures of metals which do not alloy with each other, e.g. tungsten-copper, tungsten-silver, carbon-copper, etc. In certain cases the value of the sintered product depends upon a controlled residual and interconnected porosity which is subsequently filled with oil, as in the manufacture of self-lubricating bearings. Here, perhaps, is a closer analogy to blotting paper and ink.

In the sintering process, the pressed body contracts as the pores are eliminated, and allowance has to be made for this when producing components to be used direct without final machining operations.

Down the Ages

Ample evidence exists that articles have been made from metal powder in various parts of the world from the earliest times. This is particularly so in the case of metals of comparatively high melting points, i.e. above 1,000° C., since it is only during the last two centuries that means have been available for producing the high temperatures necessary for melting.

Gold, silver, copper and iron figured prominently in the society and culture of Egypt before 1200 B.C., and powder metallurgical methods were used by the Incas before the Columbus era, in converting platinum grains into the more massive form by fritting with a metal of lower melting point, such as gold.

Malleable platinum was produced in the early years of the 19th century from metal powder which was sintered and forged, and later in that century Sir Henry Bessemer, famous for his work in the manufacture of steel, embarked on the manufacture of brass powders which were produced by machining metal billets and flattening the turnings by rolling.

Powder metallurgy is an art which has been part of the human story from the earliest times, but industrial interest in it and a technological approach to it had to await the discovery of the incandescent lamp and the active search for satisfactory lamp filament materials in the early years of the present century. The present material used, namely tungsten, is produced by powder metallurgy methods, since its melting point of nearly 3,400° C. put it out of reach of melting processes.

The need for satisfactory wear resistant materials for dies in which tungsten may be drawn into wire at high temperature led to the development of the sintered carbides which are now used so extensively in machine tools. This field, however, has developed only in the last 30 years, in which time also has been seen the development of permeable sintered bodies for self-lubricating bearings. Powder metallurgy showed sig-

nificant progress in the field of general engineering only during and since the last war.

Manufacture of Metal Powders

There is a very wide range of possible methods for the manufacture of metal powders, each resulting in a product having its own characteristics. The powder particle may be dense, porous or hollow, and, depending upon the process employed, may be spherical, flattened, angular or dendritic. The primary production processes may be categorised as reduction of oxides and salts, thermal dissociation of metal compounds, electrolysis and atomisation.

Iron, copper, tungsten and molybdenum are made by reduction of oxides. The reduction of salts for the moment is confined to treatment of ore concentrates of copper, nickel and cobalt which are reduced by high pressure hydrogen from solution.

The thermal dissociation process is restricted almost entirely to nickel and iron, which are first converted to gaseous carbonyls, and then dissociated at a suitable temperature and pressure back to the metal powder. Electrolysis opens up greater scope in that most metals can be electrolysed from solution satisfactorily, but perhaps the most significant development in recent years in the manufacture of metal powders has been that of atomisation. Basically, this consists of forcing a molten metal through an orifice and then breaking up the stream with a jet of gas or water. The particles of metal formed by the jet solidfy extremely rapidly and, although the atmosphere may be air, only superficial oxidation take place. If necessary, an inert gas atmosphere can be employed. The importance of this particular process is related not only to the great variety of metals and alloys to which it can be applied, including very high melting point metals, but also to the fact that it is comparatively cheap, yet yielding good quality powder.

Metal powder manufacture is vitally important to the powder metallurgy industry, since it can have a significant bearing upon the cost of the final product. This is so because in most powder manufacturing processes the metal has to go through the various processes of extraction, melting and solidification before disintegration. It is, therefore, especially significant that recent work has shown the possibility of being able to produce high quality cheap metal powders by the direct treatment of ore concentrates.

Testing of Metal Powders

The physical and chemical properties of a metal powder can influence its behaviour during subsequent compaction and sintering. It is essential, therefore, to be able to measure the properties of powders with satisfactory accuracy. Considerable study has been devoted to the methods of measuring these properties, and powder metallurgy has drawn to a considerable extent upon basic principles used in other branches of science to place this aspect on a satisfactory scientific basis. The microscope plays an important role in studying shape, size and distribution of particles. The specific surface in metal powders is measured by the permeability of a bed of powder to permeation by air or other gases. It can also be measured by studying the adsorption of an inert gas such as nitrogen on to the powder at sub-zero temperatures. Chemical properties may be examined by conventional means, and the determination of the extent of surface contamination of the powder by oxygen or other impurities is of particular importance. The packing and moulding properties of powders are important because, if a powder occupies a small volume in the uncompleted state, the extent to which it has to be compressed in a die should determine the stroke of the press which is used. Generally, powders of high specific density involving short compressing distances are to be preferred in mass production.

Compaction

Compacting is usually the stage which limits the shape and size of components prepared by powder metallurgy. During compaction there is considerable resistance to flow, due to frictional forces between the particles of powder and between the powder and the die walls. The transmission of an external pressure through a body of fine powder is only possible over short distances, so that the production of compacts of uniform density is difficult.

When a compact is prepared by pressing powder in only one direction, the walls and base of the die being held firmly in position, the density of the compact is not uniform ; the highest density being at the surface in contact with the moving punch. A compact of higher uniformity can be obtained by pressing the powder in two opposite directions simultaneously. Density maxima are then obtained at both top and bottom of the compact, with the lowest density in the centre. If the required component has large variation in thickness in the pressing direction, then, during compaction, the movement of the punch at points corresponding to the variations needs to be different. By using a multiple punch die the compression can be controlled so that a satisfactory product is obtained.

The size and shape of a component which can be prepared by compacting is limited. During compaction high pressures are required, and the capacity of the presses available limits the area of cross section of the compact. In addition, the length in the pressing direction must be related to the area of cross section. If the ratio of the length to the width of a compact of square cross section is greater than one, then the difference in density between the top and bottom of the compact is likely to be greater than 10% if the compaction is carried out in one direction only. The shape of the component is also restricted. Lateral projections can readily be catered for, but if an undercut is required, this must be obtained by a subsequent machining operation. The formation of holes in the direction of pressing presents no difficulties, but holes in any other direction must be made at a later stage. Abrupt changes in section are to be avoided, as also are thin sections and designs which require feather edges on either the compact or die.

The majority of the pressing carried out in practice uses one or other of these methods, but a number of alternative techniques may now be used in special cases, all aimed at producing a compact more uniformly pressed. The production of metal sheet continuously from metal powders by rolling and extrusion are attractive processes which have been examined by a number of workers. Extrusion is being used in the production of rods from hard, brittle powders such as carbides, whilst rolling is being developed for copper, nickel and iron and their alloys.

Pressure can be applied to a body more uniformly by hydrostatic means, and this method is being employed

in the manufacture of certain complex shapes. In this process the powder is fed into a mould made of rubber or latex or similar material. This is then immersed in a fluid such as oil, and the oil pressure increased to the desired level by pumping. Thus, the particular shape is compressed at uniform pressure in all directions to a high density, and difficulties associated with conventional mechanical pressing methods are overcome.

A further technique, as yet comparatively undeveloped is that of slip casting metal powders. In this process a slurry of the powder is made with a suitable liquid and this is poured into a mould of the required shape, the liquid of the slurry being absorbed by the material of the mould. In this way a powder form is built up on the surface of the mould and grows in thickness as the liquid constituent is absorbed by the mould wall.

Sintering

The driving force behind the sintering process is primarily the energy associated with the surface of the powder particles. In any system the tendency is always to proceed to the minimum level of energy, and in a sintered body there is a force existing to reduce the surface area. This means that the size of the pores tends to decrease, and they should ultimately disappear completely, providing there is no force in the opposite direction preventing it. Normally, such an opposing force is created by gases which accumulate in the pores when they are completely isolated, and when this occurs sintering in a vacuum will often effect considerable improvement.

In general, increasing the sintering temperature will increase the rate of sintering and the formation of a high density product. It is general practice in sintering to use the highest temperature, short of the melting point, which is economically practicable. The molten phase may be of a temporary nature, since a substance may alloy with the solid phase and produce a new solid alloy, or it may remain throughout the sintering process if there is little or no alloying with the solid phase. In either case the presence of a liquid phase accelerates the sintering process considerably by removing films from the surface of the remaining solid particles and expelling gases trapped in the body. The percentage of liquid phase permitted is of the order of 15% since if it were greater than this the bodies would distort, or even collapse completely.

By the process of infiltration—in which a sintered skeleton of a high melting point metal is allowed to absorb a molten metal of lower melting point—it is possible to combine metals of widely differing characteristics, which may not normally alloy, e.g. silver-tungsten and copper-tungsten for electrical contacts and welding electrodes; copper-graphite for communtator brushes; and iron-copper alloys for compressor blading.

The pressing and sintering may be carried out in one operation by compacting at an elevated temperature, usually in graphite moulds. Plastic deformation and sintering would take place simultaneously, giving a product having a recrystallised structure and little or no porosity. Hot pressing has a number of advantages, but as yet it has not been used very widely, due to the difficulties of die material and die wear and the need to prevent oxidation of the surface of the powder particles. The use of graphite dies limits the process to metals which do not react rapidly with carbon.

Continuous furnaces are normally employed for the mass production of small sintered parts. Compacts are fed into one end of the furnace through which they are traversed on a conveyor belt or on boats which are pushed at one end. The sintered compacts are delivered at the exit end of the furnace after passing through a cooling zone.

Batch sintering is usually employed when the operation is to be carried out in a vacuum. Heating by passing an electrical current directly through sintered bars is used for very high melting point metals such as tungsten, tantalum, molybdenum, etc., in atmospheres of pure hydrogen or in a vacuum. More recently, high frequency induction heating has been employed, usually in a vacuum for the sintering of various types of carbides.

Applications

Powder metallurgy is being applied to the production of high density components for general engineering applications. Production of machine parts from powders has always to compete on an economic basis with established techniques, and the possible applications are limited by the slightly lower mechanical properties of the product as compared with the wrought materials, the high tooling and raw material costs and design considerations. In general, therefore, powder metallurgy finds major application where its use shows some technical advantage or the quantities required lead to a mass production process which economically is attractive.

For magnetic applications, the powder technique holds technical advantages in that both magnetically-hard and magnetically-soft materials possessing specific magnetic properties are produced. These included the permanent magnet alloys, which are difficult to machine and which can be made as finished magnets by sintering, and also pure iron and nickel-iron alloys for soft magnets. The particular significance of the latter application is the extent to which specific magnetic properties such as permeability and losses may be reproduced within extremely narrow limits. The manufacture of nickel-iron and nickel-cobalt-iron alloys for sealing to glass and ceramics has the advantage that, by powder metallurgy methods, the expansion characteristics can be held to within extremely narrow limits.

A variety of structural parts is made from sintered iron and steel. The sintered material usually possesses low mechanical strength and high porosity, but both these disadvantages can be eliminated to a large extent by re-pressing and re-sintering to increase the density and carburising to increase the strength of the iron, or by filling up the pores with a metal of lower melting point such as copper.

A wide range of steels is produced as sintered products from completely pre-alloyed powders, but the density after one sintering treatment is usually low. To improve the strength of the sintered material it may be given a cold forging operation, such as sizing in a die, followed by re-sintering. Such a treatment has the advantage of increasing the density, breaking down any brittle films which exist internally in the material, and producing a component within very close dimensional tolerances. Such components can be used as mechanical engineering parts under stress. The mechanical properties, with the exception of wear resistance, tend still to be slightly inferior to the cast or wrought materials. For this reason, probably the most widespread application of sintered steel is for gear wheels.

High density non-ferrous materials produced by powder metallurgy include tungsten, molybdenum and tantalum. Bars of pressed powder are sintered at temperatures near to the metal's melting point by direct current electrical heating. The sintered material is then processed down into sheet or wire.

The only commercially important alloys based on the refractory metals are the molybdenum-tungsten alloys and the tungsten-copper-nickel heavy alloys. Molybdenum and tungsten form a continuous series of solid solutions, and the strength of a molybdenum-rich alloy is greater than that of pure molybdenum ; some applications in the electronic industry require these modified properties. The "heavy alloys" are tungsten-rich alloys containing up to about 10% of copper and nickel combined. The powders are mixed, compacted and then sintered at a comparatively low temperature in the presence of the liquid phase. The high density products are used for balance weights, for the screening of radioactive materials and for electrical contacts.

Tantalum is becoming increasingly important with its sister metal niobium in both the atomic energy and the electronic fields. In nuclear engineering both are important in the form of containers for the fuel used. In the electronic field tantalum is being used for capacitors and for electrodes in radio valves. Both materials are made by sintering pressed bars by direct current heating in a vacuum, and afterwards processing into sheet, wire or tubing.

Production of non-ferrous structural parts from powder on a commercial scale has, so far, been rather limited. The preparation of unalloyed copper compacts for the electrical industry, using electrolytic, atomised or hydrogen-reduced powder, is carried out on a limited scale. The soft nature of the powder allows compaction to give densities of up to 95% of the theoretical value, and after sintering in a protective atmosphere at between 800° and 1,000° C. strengths near to those of cast material may be obtained.

One of the most interesting developments of importance to the aircraft industry has been the preparation of high strength aluminium-alumina alloys by sintering and extruding fine aluminium powder. A structure having a fine grain size which is stable at elevated temperatures may be obtained, due to the dispersion of alumina in the grain boundaries. This type of structure cannot be produced by conventional melting and casting methods. Composite copper-lead bearings are another type of material which cannot easily be made by methods other than powder metallurgy.

The widest applications for powder metallurgy so far exploited are in the production of both ferrous and non-ferrous materials containing a controlled amount of porosity distributed in a specified manner.

Oil-impregnated, porous non-ferrous bearings are used extensively throughout the engineering industry. The most frequently used alloys contain 5–12% tin, 0–6% graphite and the balance copper, and they are prepared by mixing together powdered copper and tin with finely divided graphite. An organic binder is added during mixing, and its removal at between 400° and 500° C. promotes the formation of connected porosity.

Filter elements can be made from metal powders in a similar manner to porous materials for bearings, and the material most frequently employed is pre-alloyed bronze powder (90% copper, 10% tin). Stainless steel filters are also important, and in either case it is important that the powder particles are nearly spherical and of uniform size. By suitable selection of powder and sintering conditions, filters having pore volumes of between 10% and 60% can be prepared.

Porous iron and steel are being used to an increasing degree for bearing applications, because of the high strength obtained with these components and the higher pressures which they can withstand.

Both porous ferrous and non-ferrous materials are used extensively in the chemical and other industries for filtration, and have the advantage over ceramic filters of greater strength resistance, to shock and the ease with which they can be jointed to metal. Such filters can also be made from stainless steel, where the corrosive nature of the material filtered requires it. Porous materials have also been employed for distributing de-icing fluids to the leading edges of aeroplane wings.

The carbides of the high melting point metals such as tungsten and titanium are hard and brittle, and when bonded with another metal such as cobalt they possess outstanding properties as cutting tools. A wide range of sintered bonded carbides is now available for machine tools, dies and rock drills, etc., the composition selected being related to the particular application. The most popular variety used for machine tools has been tungsten-carbide bonded with cobalt, but the factors influencing the efficiency of machining are complex, and it is only in recent years that the evaluation of various types of machine tools has been investigated. As a result, some of the more complex sintered carbides, such as those containing the mixed carbides of tungsten and titanium bonded with cobalt, may replace the older and simpler tungsten carbide.

The preparation of engineering components for high temperature service by powder metallurgy is a new development which, as yet, is not of great commercial importance. The importance of this branch of powder metallurgy is likely to increase, however, due to the continued desire for materials to operate at high temperatures.

High temperature alloys of commercial importance have been prepared by pressing and sintering powders, and the properties obtained compare with those found for cast alloys. Alloys examined have included the chromium-cobalt-tungsten alloy, Vitallium, and a number of nickel-iron-chromium base alloys. In order to obtain a sintered product of low residual porosity, close control of the powder characteristics and the sintering conditions is necessary.

Future Trends

As the cost of high quality metal powder decreases, so the powder metallurgy product becomes more competitive with cast or machined components. Methods of producing large quantities of comparatively cheap powder are being developed, and the wide application of powder metallurgy to the preparation of engineering components will largely depend upon the cost and quality of the powders available. The mechanical strength of sintered components also needs to be comparable with materials made by conventional techniques. Modified techniques for obtaining high strength products are therefore likely to be developed based upon the use of pre-alloyed powders, higher sintering tem-

peratures, infiltration techniques, and, possibly, activated sintering.

The importance of powder metallurgy in the field of high temperature materials is likely to increase considerably. The production of components from alloys able to withstand higher and higher operating temperatures continually increases in difficulty, and their preparation from powders is a possible alternative approach. It also seems likely that composite metal-refractory bodies will find increasing application at elevated temperatures, either when the refractory phase is bonded by a metal, or when a metal or alloy contains a comparatively small percentage of dispersed refractory. In either case, powder metallurgy is likely to be the method employed in their fabrication.

The continuous rolling of metal powder to form sheet is a process which, as yet, is not in commercial operation, but with the availability of cheaper powders it is likely to become important. Development work is being carried out, and when production is on a commercial scale large quantities of powder are likely to be consumed.

Large Arc Furnaces

Metalectric Exhibition in Sheffield

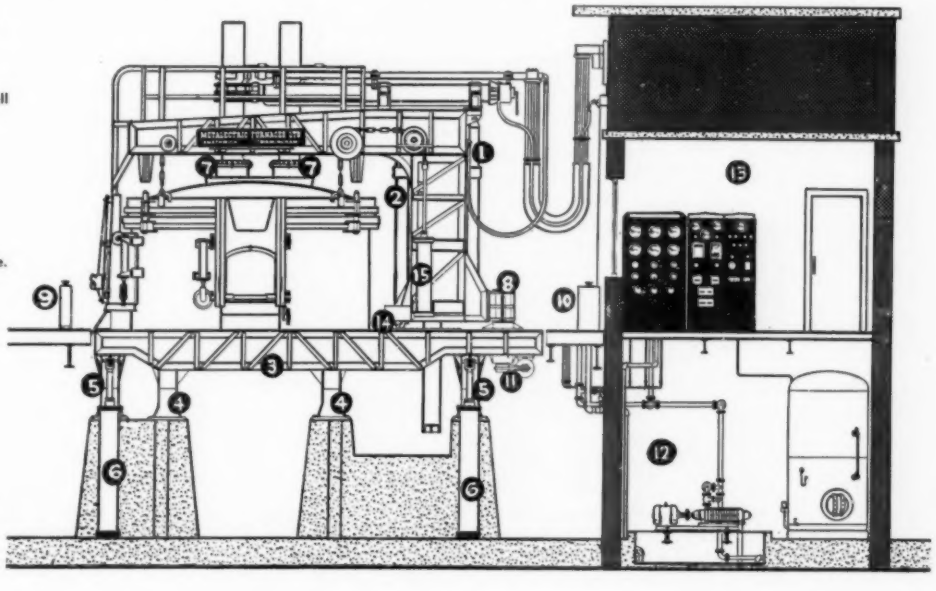
IN the immediate post-war years, arc furnaces of 25–40 tons capacity were considered large, and this method of melting was confined mainly to special alloy steels, particularly those in the stainless group. There is now, however, a trend towards the use of arc melting for less complex steels, and for this purpose furnaces of 100–150 tons capacity are being installed. To meet the expected demand for units of this size, Metalectric Furnaces, Ltd., have designed a new range of large arc furnaces with capacities up to 200 tons, which was introduced to steelmakers at a recent exhibition in Sheffield, in which the central feature was a "working" model of a typical furnace in this range.

Metalectric Furnaces have been making direct arc furnaces for the steel industry for over twenty years, and during that time many design features have been developed. The design of the new range of large capacity furnaces has evolved from earlier experience with furnaces of up to 50 tons, and noteworthy features of it were demonstrated at the exhibition by means of the model illustrated on page 276.

The furnace is of the swing bridge design, and the mechanical structure comprises two distinct and separate assemblies, namely a furnace shell supported from the foundations on its own rocker system; and the tilting platform and swing bridge structure—also supported from the foundations on its own rocker system in such a way that care is taken of the out-of-balance effect when the swing bridge is in the open charging position. The shell and tilting platform are connected by flexible links. This arrangement ensures that shock loading on charging is transmitted through the shell and rockers to the foundations and not to the swing bridge and roof gear mechanisms. Furthermore, there are no extraneous stresses imposed on the shell of the furnace, all the heavy electrode gear being carried from the swing bridge structure. The design also permits the shell being freely exposed on all its surfaces to provide for free heat radiation and the elimination of "hot spots." The shell rim is replaceable in sections, so that any part damaged mechanically during charging, or distorted or badly burned in service, can be replaced readily without excessive cost.

The swing bridge carries the roof by means of a four chain suspension, connected to the lifting mechanism, and the design is such that quick roof replacement can

1. Electrode raising cylinder.
2. Electrode counterbalance cylinder.
3. Tilting platform.
4. Rockers for independent shell support.
5. Platform rockers.
6. Tilting cylinder.
7. Electrode economisers.
8. Pivot point.
9. Pouring control point.
10. Hydraulic control point.
11. Cylinder for rotating bridge.
12. Pump house.
13. Control room.
14. Bridge roller track.
15. Roof raising cylinder.



Drawing showing swing-bridge mechanism applied to a 90-ton furnace.

be effected without the necessity of extensive dismantling of ancillary equipment. The electrode arms, too, are supported from the swing bridge structure, so that when the furnace is tilted there is no deflection on them. The electrode clamps, following established design, are hydraulically operated, a hydraulic release mechanism permitting the electrodes to be slipped from a remote position.

The standard design of furnace incorporates hydraulic cylinder of ample capacity, providing for the correct tilting operation and position when pouring and slagging. The slagging door is also operated by hydraulic means, as is the roof lifting gear which is attached to the swing bridge. The swing bridge mechanism is activated either by a hydraulic cylinder or electric motor, through suitable gears, and in all cases the movements are interlocking, providing for full safety precautions during the furnace operation.

Arc regulation can be either by standard Metalectric Electrolic (oil hydraulic) system or by wholly electrical means, at the choice of the user. Advantages claimed for the hydraulic system include low inertia, and the possibility of incorporating hydraulic counterbalance on the electrode masts, and of providing for the automatic removal of the electrodes in the event of a power failure.

Universal Beams and their Applications

BRITISH constructional engineers will have at their disposal early next year new steel sections giving greater strength for less weight and permitting appreciable reductions in fabricating costs. This was announced at a recent meeting of the Institution of Structural Engineers when a paper on "Universal Beams and their Application" was presented by Mr. S. Barlow and Mr. G. Foster of Dorman Long.

Mr. E. T. Judge, director and chief engineer, Dorman Long, who also spoke, said that with intense competition from other methods of construction, it was of national importance that the British constructional engineer should be highly competitive in world markets. The position to-day demanded a maximum efficiency and highest productivity in all engineering effort. In this regard, the approaching completion by Dorman Long of their new Lackenby universal beam mill designed for rolling a new and wide range of efficient beams and column sections was of great importance. It would have a far reaching impact on all structural engineers and other users. A comprehensive range of universal beams varying from beams 36 in. deep with 16½ in. wide flanges to 6 in. deep with 6 in. wide flanges would be produced.

The production of universal beams represents the climax of the Dorman Long £60 million development scheme. The universal mill is costing £18 million, and the adjoining Lackenby steel plant was completed in 1953 at a cost of £8¼ million. The authors of the paper described the new mill as, not only the first of its kind in this country, but the most advanced of this type in the world. The last full range beam rolling mill to be installed in the U.S.A. dates back to 1930 and the Lackenby mill embodies great advances in mill engineering and practice achieved since then. The initial supply of rolls to cover the new range of beam and column sizes to be produced cost £1 million.

An increase of up to 10% in efficiency over the present British Standard beams will be offered by the universal beams. There will also be available a large number of beam sizes having heavier weights and greater strengths than are at present rolling in this country. Costly fabrication now often necessary when using British Standard beams will be eliminated and, in consequence, the capacity of the fabricating shops should increase. Actual steel structures which have been re-designed using the new range of universal beams show savings in weight varying from 5% to 10%. In overseas markets the British constructional engineer able to design structures based on the new beams should be more favourably placed than when, as now, he is restricted to the use of British Standard beams.

Northern Rhodesia's Niobium Deposits

NORTHERN RHODESIA may have one of the most extensive deposits of niobium in the world, says Barclays Bank D.C.O. in its *Overseas Review*. The article states that the metal has been discovered in more than normal richness in the Feira area. It also reports that two new deposits of pyrochlore (niobium ore) have been discovered in the Southern Province of Nyasaland by the Geological Survey Department. The new deposits are both situated near Zomba, and further investigations are in progress.

An interesting copper development is reported from Nchanga, where work has started on a second open-cast copper pit which is now being "stripped." First production is expected to come from the pit in about one year's time. Total ore reserves at Nchanga are now estimated at 164 million tons, which under present circumstances should last 40 years. An increase in the production of copper concentrates to about 500 tons monthly at the Mtuga Mine has been forecast.

Elastic Moduli and Tensile Properties of Titanium-Carbon and Titanium-Aluminium-Carbon Alloys

By H. Brooks, G. I. Lewis and J. I. M. Forsyth

(*Royal Aircraft Establishment, Farnborough*)

Although tensile tests and dynamic measurements on hot-rolled strip confirmed the beneficial effect of carbon additions on the tensile and shear moduli of titanium, carbon is considered unlikely to be used as a modulus-raising addition in commercial sheet alloys unless its effect on service temperature ductility can be lessened. Ternary alloys containing both carbon and aluminium in amounts sufficient to give a significant improvement in modulus were found to be brittle.

BECAUSE the best titanium sheet alloys have outstanding specific strengths over the range −60° to 400° C., they are considered promising materials for the primary structures of aircraft and missiles with speeds up to M3·5. Perhaps their chief disadvantage is that their specific elastic moduli are lower than those of alternative materials, particularly at the higher temperatures. In examining possible methods of improving the moduli, several titanium-carbon alloys have been tested. With an atomic size factor of −47·5%, carbon has only a small solid solubility in α-titanium, as shown in the detail of the titanium-carbon phase diagram[1] reproduced in Fig. 2. The maximum α-solubility is 0·48% at the peritectoid temperature and diminishes to less than 0·1% at 500° C. The second phase in alloys with more than 0·1%C is usually described as TiC, although it has a wide composition range, as shown in Fig. 1. This is a composite diagram based on the work of Cadoff and Nielsen[1] and Bickerdike and Hughes.[2] Smithells[3] quotes a Young's modulus of $45{\cdot}8 \times 10^6$ lb./in.² and a specific gravity of 4·93 for TiC; it has a cubic structure of the NaCl type. So a worked Ti-2%C alloy, say, in equilibrium below 500° C., consists of an α-solid solution, containing less than 0·1%C, and particles of titanium carbide. High modulus second phases such as this are known to raise the modulus of the alloy above that of the matrix. The effect was first observed in aluminium alloys containing silicon or intermetallic compounds formed from the melt,[4] and later in aluminium alloys containing titanium carbide particles introduced by powder metallurgy techniques.[5] Tests by Larsen *et al.*[6] indicated that TiC particles exert the same beneficial effect in titanium-carbon alloys; the Young's modulus of their bar alloys increased from $16{\cdot}0 \times 10^6$ lb./in.² at 0·47%C to $21{\cdot}5 \times 10^6$ lb./in.² at 1·91%C. The first objects of the present work were to check whether similar improvements could be obtained in alloys rolled to strip, and if so, whether they were retained at elevated temperatures.

Preliminary Property Survey of Titanium-Carbon Alloys

First a set of twelve 20g. buttons with nominal carbon contents ranging from 0·4 to 2·6% in 0·2% steps were prepared and processed to strips for testing at room temperature or 400° C. The buttons were made by melting magnesium-reduced titanium sponge and electrographite in a tungsten electrode furnace. Analyses and hardness tests on three melted 10g. samples of the sponge gave the following results:—

Sample	O%	H%	C%	Fe%	Hardness (D.P.N.)
d	0·062	0·0013	0·013	trace	159
h	0·073	0·0018	0·017	0·110	178
o	0·053	0·0010	0·020	0·018	152

The buttons were reduced to strips about 0·06 in. thick by hammering and rolling; the preheating temperature was 1,000° C., except for the last two passes, which were

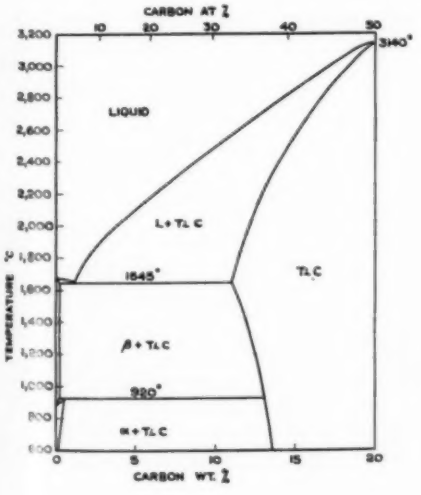


Fig. 1 (left).—Titanium-carbon constitutional diagram up to 50 atomic % carbon.

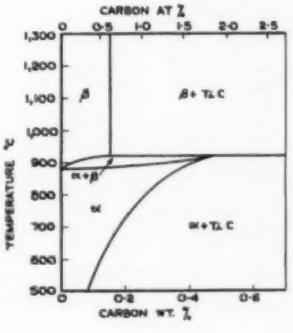


Fig. 2 (right).—Detail of titanium-carbon constitutional diagram.

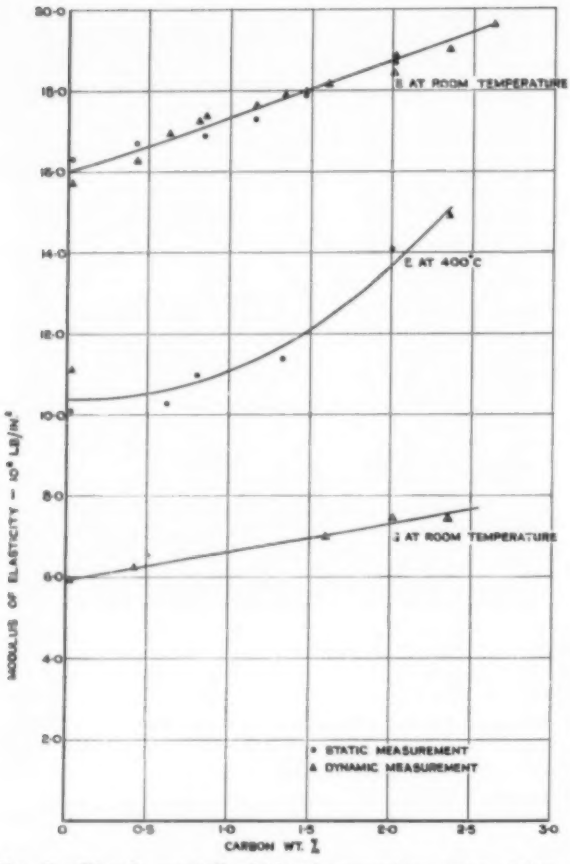


Fig. 3.—Elastic moduli of titanium-carbon alloy strips made from 20g. buttons.

made from 850° C. Cracks were ground out as they were formed, and the weights of the final strips, expressed as percentages of the button weights, were as follows :—

Nominal %C ..	0·4	0·6	0·8	1·0	1·2	1·4
Strip weight ..	87	89	93	91	91	86
Nominal %C ..	1·6	1·8	2·0	2·2	2·4	2·6
Strip weight ..	86	86	79	80	70	72

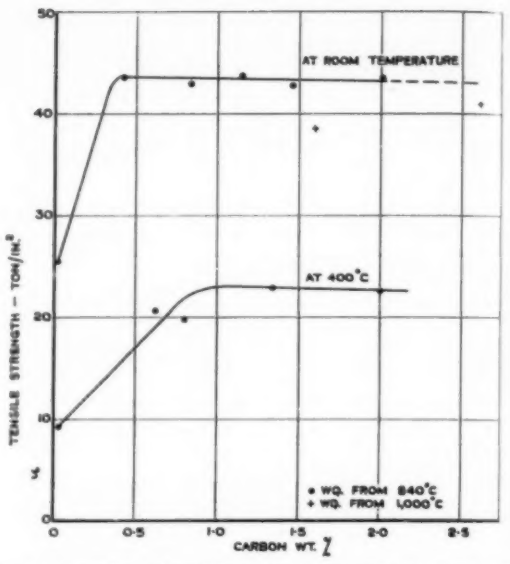


Fig. 4.—Tensile strengths of strips made from 20g. buttons.

These figures give a rough indication of the hot-workability of the alloys ; those around the eutectic composition behaved well, but workability deteriorated at higher carbon contents.

The strips were descaled, water quenched after annealing 30 minutes at 840° C., and again descaled. They were then milled on the edges to a rectangular shape suitable for dynamic modulus measurements, which were made in the Physics Division of the National Physical Laboratory. The strips were then machined to tensile test pieces and were tested at room temperature or 400° C. ; two of them were given a further treatment of 15 minutes at 1,000° C., followed by water quenching and descaling, before tensile testing. The results are shown in Table I and Figs. 3, 4 and 5.

Room temperature E (Young's modulus) appeared to increase linearly with carbon content at a rate of $1{\cdot}4 \times 10^6$ lb./in.² or 8·75%/1 wt.-%C, i.e. somewhat more slowly than indicated by the results of Larsen *et al.*[6] Fig. 6 shows that the observed rate is intermediate

TABLE I.—RESULTS OF TESTS ON TITANIUM-CARBON ALLOY STRIPS MADE FROM 20g. BUTTONS.

Strip Number	Condition	Carbon (%)		Room Temperature Tests*						400° C. Tests*				
		Nominal	Analysed	Tensile Strength (tons/in.²)	0·1% Proof Stress (tons/in.²)	Elongation (%)	E_S (10^6 lb./in.²)	E_D (10^6 lb./in.²)	G_D (10^6 lb./in.²)	Tensile Strength (tons/in.²)	0·1% Proof Stress (tons/in.²)	Elongation (%)	E_S (10^6 lb./in.²)	E_D (10^6 lb./in.²)
W1	30 min. at 840° C., W.Q. ..	0·40	0·42	43·7	39·3	23	16·7	16·29	6·240					
W2	" " "	0·60	0·62					16·96		20·7	10·3	18	10·3	
W3	" " "	0·80	0·84	43·1	31·4	25	16·9	17·40						
W4	" " "	1·00	0·80					17·29		19·9	9·2	16	11·0	
W5	" " "	1·20	1·15	43·8	35·1	25	17·3	17·66						
W6	" " "	1·40	1·33					17·89		22·9	11·7	12	11·4	
W7	" " "	1·60	1·46	42·8	31·2	20	17·9	18·00						
W8	" " "	1·80	1·60					18·19	7·013					
W8	15 min. at 1,000° C., W.Q. ..	1·80	1·60	34·6	23·5	16	17·4	18·28						
W9	30 min. at 840° C., W.Q. ..	2·00	2·00					18·48		22·7	10·3	10	14·1	
W10	" " "	2·20	2·01	43·5	32·4	12	18·7	18·88	7·446					
W11	" " "	2·40	2·35					19·03	7·480					14·94
W12	" " "	2·60	2·62					19·64						
W12	15 min. at 1,000° C., W.Q. ..	2·60	2·62	37·0	25·5	8	19·2	19·56	7·467					
0†	20 min. at 825° C., W.Q. ..	0	0·02	25·5	15·4	47	16·3	15·72	5·94	9·3	4·0	40	10·1	11·11

Notes :— * Tensile test pieces from strips W1–10 had parallel portions 1·25 in. long and 0·25 in. wide, that from W12 a parallel portion 1·125 in. long and 0·188 in. wide.

† Larger strip made from same batch of sponge as W series, but without any additions. Average longitudinal tensile results quoted for comparison.

Symbols :—E_S Young's modulus from tensile stress-strain curve.
E_D Young's modulus measured dynamically by a resonance method.
G_D Shear modulus measured dynamically by a pulse technique.

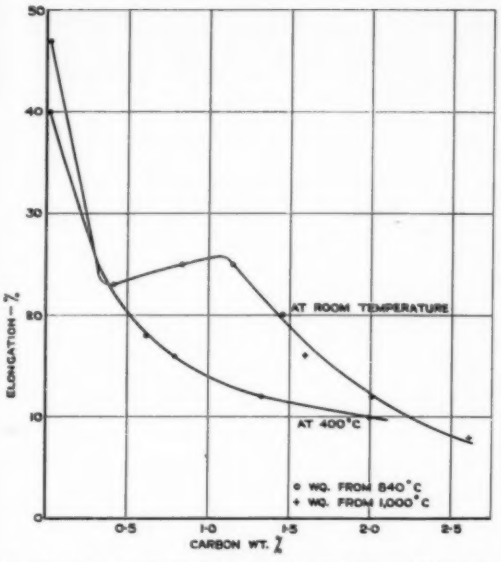


Fig. 5.–Tensile elongations of strips made from 20g buttons.

between those calculated for alloys which were assumed to consist of continuous lamellae parallel or perpendicular to the stress axis. The form of the experimental E versus composition relation at 400° C. is less certain, but it does not appear to be linear; the average rate of increase was $1{\cdot}8 \times 10^6$ lb./in.^{2} or 17·3%/1 wt.-%C. Room temperature G (shear modulus) increased at a rate of $0{\cdot}69 \times 10^6$ lb./in.^{2} or 11·6%/1 wt.-%C.

To achieve parity in specific E with a steel having $E_{20°} = 31{\cdot}4 \times 10^6$ lb./in.,^{2} $E_{400°} = 27{\cdot}0 \times 10^6$ lb./in.^{2} and specific gravity = 7·76,* a titanium alloy of specific gravity 4·51 must have $E_{20°} \geqslant 18{\cdot}3 \times 10^6$ lb./in.^{2} and $E_{400°} \geqslant 15{\cdot}7 \times 10^6$ lb./in.^{2} Fig. 3 indicates that a Ti-2·5%C alloy would do this; its estimated properties are :—

	Tensile Strength (tons/in.^{2})	Elongation (%)	E (10^6 lb/in.^{2})
At room temperature ..	43	8	19·4
At 400°	22	8	15·7

* These are typical values for Firth-Vickers 448 ferritic stainless steel.

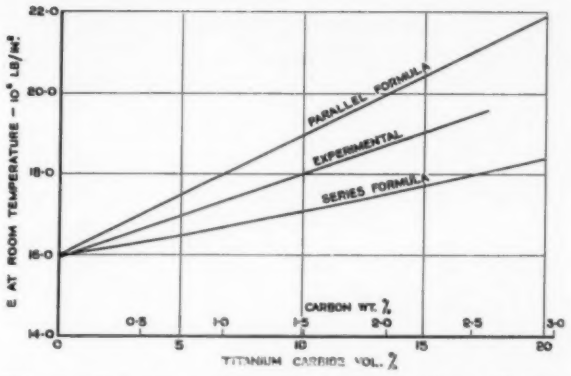


Fig. 6.—Young's moduli of titanium-carbon alloys—comparison of experimental and calculated values.

To make it attractive both strength and ductility would have to be improved by further alloying or other means.

An interesting feature of Fig. 5 is that room temperature ductility had a peak value at 1·1%C, i.e. at about the eutectic composition. The relative fineness of most of the carbide particles in the eutectic alloy (Fig. 7) may have been responsible for this; hypereutectic alloys contained increasing amounts of coarser carbide such as that shown in Fig. 8.

Most of the results in Table I are for test-pieces which had been water-quenched from 840°C., which would be expected to retain about 0·3%C in solution. Quenching from 1,000° C., to obtain a transformed β-matrix with only 0·15%C in solution, gave somewhat lower strengths but similar elongation and modulus values.

Further Examination of Hypereutectic Titanium-Carbon Alloys

As the preliminary survey indicated that an alloy with 2·5%C would have the desired modulus values, a 210g. $1\frac{3}{4}$ in. diameter ingot of this composition was prepared, to permit a fuller examination of its tensile properties and response to heat-treatment. During hot-pressing to a 0·43 in. thick slab, considerable cracking occurred; temperatures of 890° C. and 1,000° C., in the α + TiC and β + TiC fields, were tried at different stages in the pressing, but no difference in working behaviour was

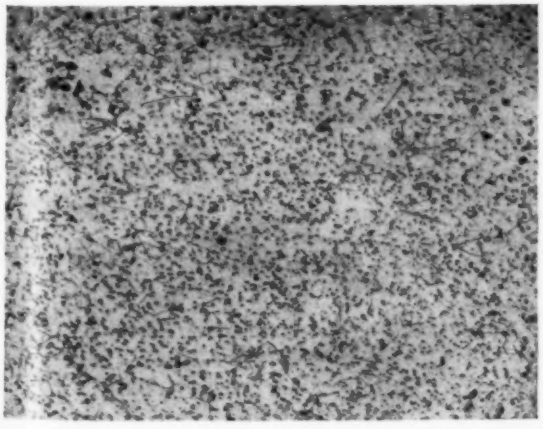


Fig. 7.—Ti-1·15% strip W5. Etched 12 sec. in 1/12/87 $HF/HNO_3/H_2O$ mixture. × 100

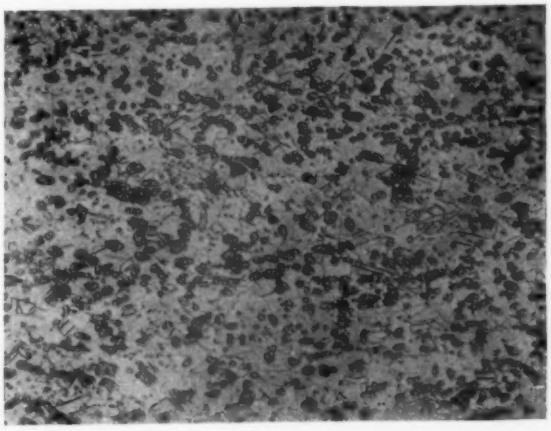


Fig. 8.—Ti-2·62%C strip W12. Etched 12 sec. in 1/12/87 $HF/HNO_3/H_2O$ mixture. × 100

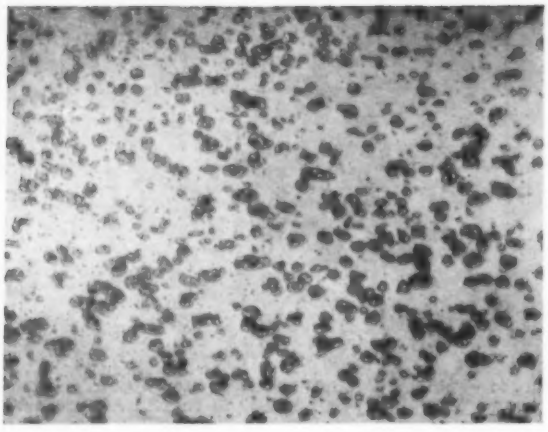


Fig. 9.—Head of Ti-2·43%C test piece R2. Unetched. × 100

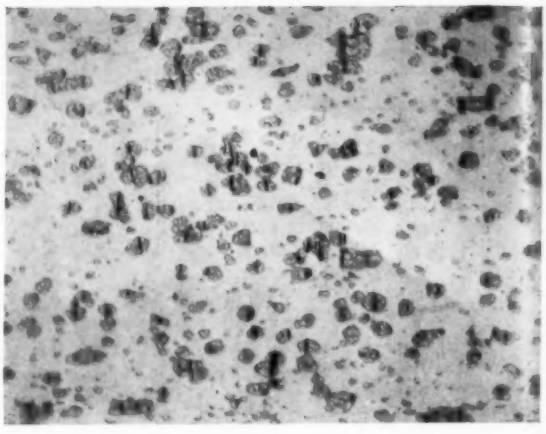


Fig. 10.—Gauge length of Ti-2·43%C test piece R2. Unetched. × 100

observed. After descaling and grinding, the slab was reduced to 0·163 in. thickness by rolling from 980° C. Surface and edge cracking became prohibitive at this stage, and rolling was therefore discontinued. After milling off the cracked surface layers, sufficient sound material remained for three longitudinal 4 in. × 0·75 in. × 0·10 in. tensile test-pieces. These were annealed one hour at 900° C. and furnace cooled to obtain a matrix of equiaxed α-grains with a minimum of carbon in solution. The results of tests on the strips are given in Table II.

E values were similar to those estimated previously, but strength and elongation were lower, suggesting that furnace cooling from 900° C. had caused carbide to separate in an unfavourable form. Photomicrographs of sections from the head and gauge length of one of the test-pieces are shown in Figs. 9 and 10; cracking of some of the carbide particles by the tensile straining is evident in Fig. 10. The volume percentage of carbide was estimated as 18% by areal anlysis; the average particle size was 0·00039 in. × 0·00061 in.

The rolling of thin strip with the desired carbon content of 2·5% having proved impracticable, a 288g. 1¾ in. diameter ingot with the lower nominal content of 1·75% was prepared. From the preliminary survey, this carbon content was expected to give the required E at room temperature, although not at 400° C. Some cracking occurred during hot-pressing to a 0·57 in. thick slab, and much more during subsequent rolling to strip. Preheating temperatures from 800° C. to 1,030° C. were tried in the course of the processing, but cracking always occurred. By grit blasting and pickling, most of the surface defects were removed from an area of the sheet sufficient for five longitudinal and three transverse 4 in. × 0·75 in. strips. The final rolling temperature of 1,020° C. produced a structure consisting of large elongated and transformed β-grains, with TiC particles. Some difficulty was experienced in converting the matrix to equiaxed α-grains; samples from different parts of the sheet differed considerably in the ease with which they could be recrystallised. Eventually, six strips were tested after annealing two hours at 800° C. and furnace cooling, and two were reduced 20% by cold-rolling before being treated in the same way. The results of tensile and other tests are given in Table III.

TABLE II.—RESULTS OF TESTS ON Ti-2·43%C STRIP.*

Test Piece	E_{20}* (10^6 lb./in.²)	E_{400}* (10^6 lb./in.²)	Final Tests at Room Temperature				
			Tensile Strength (tons/in.²)	0·1% Proof Stress (tons/in.²)	Elongation (%)	E (10^6 lb./in.²)	Hardness (D.P.N.)
R1	19·3	16·3, 15·9	36·6	31·4	5	19·3	234
R2	19·2	15·7, 15·8	35·6	30·6	6	19·3	
R3	19·6	15·4, 15·1	35·9	32·4	5	18·9	

Notes:—* Analysed Composition: 2·43%C, 0·062%O, 0·042%N, 0·0038%H. Condition: Hot rolled from 1,000° C., annealed 1 hr. at 900° C. and furnace cooled.

Longitudinal E values determined in tensile tests varied widely, and were mostly well below the levels indicated by the preliminary survey. From micro-examination of sections from the test lengths and heads of the broken tensile test pieces, it was concluded that the low E values of the cold-rolled samples could be attributed to some of the carbide particles having been cracked during cold-rolling, and that particle size variations might have been responsible for the scatter in the static E values of the other longitudinal test-pieces.

Trial of Cladding Technique for Rolling Hyper-eutectic Alloys

The mechanism of the surface cracking of the Ti-2·43%C and Ti-1·57%C alloy slabs during rolling was believed to be as follows. Extension of the slab by rolling causes the larger carbide particles to crack transversely and the cracks tend to propagate into the matrix. Small cracks of this type formed within the slab are healed by the pressure welding action of subsequent passes, but those formed at the surface become oxidised and will not weld together again. It therefore seemed likely that surface layers of unalloyed titanium would prevent the cracking. To test this idea, a 300g. 2½ in. diameter ingot of nominal composition Ti-2·5%C was prepared, the top and bottom surfaces were machined flat and 2½ in. diameter discs of 0·064 in. thick commercial titanium sheet were edge-welded on to them with an argon arc torch. The clad ingot was rolled to 0·065 in. strip at 900° C., using reductions of 10 to 15% per pass. Slight edge cracking occurred during the later passes but there was no surface cracking. The strip was descaled by grit blasting and about 0·0005 in. of metal was removed from the surfaces by pickling. Micro-examination of samples from the strip showed a good

TABLE III.—RESULTS OF TESTS ON Ti-1·57%C STRIP.

Test Piece	Direction	Condition	Room Temperature Tests							400° C. Tests			
			Tensile Strength (tons/in.²)	0·1% Proof Stress (tons/in.²)	Elongation (%)	E_s (10^6 lb./in.²)	E_D (10^6 lb./in.²)	G_D (10^6 lb./in.²)	Minimum Bend Radius	Tensile Strength (tons/in.²)	0·1% Proof Stress (tons/in.²)	Elongation (%)	E_s (10^6 lb./in.²)
SL5	Long.	Cold rolled 20%, 2 hr. 800° C., F.C.	39·6	28·6	15	17·1	17·66						
ST3	Trans.	Cold rolled 20%, 2 hr. 800° C., F.C.	41·0	30·1	10	17·4	17·87						
SL1	Long.	½ hr. 800° C., F.C. ..	40·3	28·4	20·5	17·0	18·47						
SL3	Long.	" " "	39·1	27·9	12·5	18·2	18·41						
ST1	Trans.	" " "	40·1	29·9	12·5	19·2	19·23						
SL2	Long.	2 hr. 800° C., F.C. ..					18·39			18·7*	9·2*	14·5*	11·5*
SL4	Long.	" " "					18·44			19·8	10·2	14·5	10·1
ST2	Trans.	" " "					19·11			20·5	11·6	12·5	13·9
S1		" " "						7·097	2t†				
S2		" " "						7·133	2t†				

Notes:—* Tests at 436° C. in error. †† is strip thickness.

bond between the core and the claddings, which were about 0·005 in. thick; less than 1% of the carbide particles were cracked.† The results of tensile and other tests made on samples from the strip are given in Table IV.

The five heat-treatments tried produced similar elongation and E values; the latter were lower than for the unclad Ti-2·43%C strip.

Attempts to Reduce the Size of the Carbide Particles

The exceptional ductility of the eutectic alloy and the cracking, during tensile testing, of the larger carbide particles in hypereutectic alloys (Fig. 10) suggested that the effect of carbon additions on ductility would probably be lessened if the carbide particle size could be appreciably reduced. Four possible methods of securing such a reduction were considered‡:—

(1) the use of a ternary addition to refine the primary carbide;

(2) the use of a ternary addition to raise the eutectic carbon content;

(3) the use of a ternary addition to increase the maximum α-solubility of carbon, so that the carbide dispersion might be controlled by thermal treatments; and

(4) the use of powder metallurgy, carbon being introduced as TiC powder.

Eighteen elements were added in turn to a Ti-2·5%C alloy, mostly at the 0·5% level. To effect complete solution of the carbon the 5g. ternary alloy buttons were melted at 300 amp. for two minutes, inverted and then remelted in the same way. On sectioning, all the buttons showed two roughly equal zones, the carbide dendrites being coarser in the bottom zone than in the top, but none of the additions had any appreciable effect on the average size.

A survey of the available ternary phase diagrams suggested that additions of 4%V or 3%Mo might raise the eutectic carbon content, but no appreciable shifting was observed in trials with 10g. buttons which contained 1·2, 1·9 or 2·6%C.

Since carbon increases the lattice parameters of α-titanium, its solubility might be expected to be increased by solutes which contract the lattice. Aluminium decreases both the *c* and *a* parameters of α-titanium, and it does increase the solubility of carbon slightly. An examination of three Ti-Al-C alloys is described in the next section. The few other elements for which there are ternary phase diagrams do not appear to increase carbon solubility, and none of the other α-solutes which decrease the lattice parameters appears promising.

As yet no work has been done on the powder metallurgy method of obtaining a fine carbide dispersion, mainly because of the commercial scale disadvantages of the technique.

Titanium-Aluminium-Carbon Alloys

Three more alloys were made to see if the modulus-raising effects of aluminium[7] and carbon could be obtained together; their nominal compositions were Ti-6%Al-1%C, Ti-6%Al-0·6%C, Ti-2%Al-2%C. The first was made as a 550g. 2½ in. diameter ingot, which was not clad for rolling because the technique had not

† The use of claddings to facilitate the hot-rolling of titanium base alloys containing large amounts of a brittle phase is the subject of British Patent Application 35,246/56.

‡ Achieving cooling rates faster than those of arc melted buttons would be difficult inside, and clearly impossible outside, the laboratory.

TABLE IV.—RESULTS OF ROOM TEMPERATURE TESTS ON CLAD Ti-2·60%C STRIP.*

Test Piece	Condition	Tensile Strength (tons/in.²)	0·1% Proof Stress (tons/in.²)	Elongation (% on 1 in.)	E (10^6 lb./in.²)	Hardness (D.P.N.)	Bend†
Z3	10 min. at 950° C., W.Q.	32·9	23·8	6	18·1	213	70°
Z6		34·0	23·9	10	18·0		
Z1	30 min. at 890° C., W.Q.	41·2	30·7	10	17·8	264	60°
Z9		42·1	20·2	10	17·8		
Z2	30 min. at 890° C., W.Q. + 24 hr. 450° C., W.Q.	39·3	28·2	9	17·8	250	100°
Z7		38·6	27·5	8	17·8		
Z4	30 min. at 890° C., F.C.	38·8	29·6	14	17·8	266	20°
Z8		37·3	29·5	9	17·8		
Z5	1 hr. at 800° C., W.Q.	37·4	29·2	10	18·1	261	30°

Notes.—* Gas Analysis of Core—0·094%O, 0·046%N, 0·0070%H. Claddings formed from commercial titanium sheet were 0·005–0·006 in. thick each side of the strip, with a total thickness of 0·062 in.
† Bend angle at fracture over 0·25 in. radius former.

TABLE V.—RESULTS OF ROOM TEMPERATURE TESTS ON TITANIUM-ALUMINIUM-CARBON ALLOY STRIPS.

Melt	Analysis of Strip (wt.-%)					Test Piece	Condition	Tensile Strength (tons/in.²)	0·1% Proof Stress (tons/in.²)	Elongation (% on 1 in.)	E (10^6 lb./in.²)	Hardness (D.P.N.)	Structure
	Al	C	O	N	H								
Y	6·45	1·02	0·040	0·047	0·0095	Y2	30 min. at 1,000° C., W.Q.	38·8	—	<1	16·2	382	Carbide particles within and at boundaries of α-grains.
AF	6·0*	0·6*	0·045	0·023	0·0034	AF2	30 min. at 950° C., W.Q.	71·0	65·6	2	17·6	362	Carbide within α-grains.
						AF3		68·6	—	—	17·4		
						AF5	30 min. at 950° C., W.Q.	58·7	—	3	—	358	Carbide at boundaries.
						AF6	+ 24 hr. at 700° C.	59·6	—	2	17·2		
						AF1	30 min. at 950° C., W.Q. + 1,000 hr. at 500° C.	54·4	—	<1	18·3	346	Very fine carbide within and at boundaries of grains.
AG	2·02	1·99	0·050	0·037	0·0078	AG1	30 min. at 900° C., W.Q.	48·1	41·1	8	18·5	292	Primary carbide particles within α-grains.
						AG2		49·0	42·8	7	18·5		
						AG3	30 min. at 900° C., W.Q.	48·0	42·4	8	18·5	312	Grain boundary carbide also.
						AG4	+ 1 hr. at 550° C.	47·9	42·6	8	18·4		
						AG5	30 min. at 900° C., W.Q.	42·6	29·9	7	18·4	265	Precipitated carbide within and at boundaries of grains.
						AG6	+ 96 hr. at 550° C.	41·9	30·4	5	18·1		

*Nominal content.

been tried; the other two were made as 250g. 1¾ in. diameter ingots which were machined and clad with 0·03 in. thick discs of commercial titanium sheet.

Some cracking of the unclad Ti-6%Al-1%C ingot occurred during pressing at 1,000° C. to a 0·75 in. slab, and severe surface cracking occurred during subsequent rolling at the same temperature. The rolling was stopped at 0·25 in. thickness when it had become clear that a sound strip could not be obtained. Difficulties were also encountered in machining sound tensile test strips from the cracked 0·25 in. plate because of its brittleness. Only one test piece was obtained; this was tested after heating 30 minutes at 1,000° C. and quenching in water, with the results shown in Table V. The material was hard and brittle and, considering its aluminium content, its E was low. The ternary phase diagram study of van Thyne and Kessler[8] indicates that at 1,000° C. a Ti-6%Al-1%C alloy consists of carbide and α-phase containing about 0·7%C. Micro-examination of the broken test-piece revealed carbide particles within the α-grains and also, in a finer form, at the grain boundaries; the fracture was intercrystalline.

No difficulty was encountered in processing the clad Ti-6%Al-0·6%C alloy to strip, using a preheating temperature of 1,000° C., but at room temperature the as-rolled and Virgo cleaned material was brittle, and various quenching and ageing treatments failed to confer bend ductility. Three of the treatments were applied to tensile specimens, and the results of tests on these are included in Table V. All the specimens were brittle, and those that were aged after quenching from 950° C. had intercrystalline fractures.

The clad Ti-2%Al-2%C ingot was also processed without difficulty and, after making some exploratory heat-treatment trials with small specimens suitable for bend and hardness tests, three treatments were applied to duplicate tensile test-pieces, which gave the results shown in Table V. Quenching from 900° C. and so retaining about 0·5%C in solution gave the best combination of properties; both strength and E were better than for the clad Ti-2·60%C alloy, but E and elongation were slightly lower than for the unclad Ti-2·01%C strip tested in the preliminary survey. The claddings formed about 0·004 in. of the 0·064 in. total thickness of the strip. Prolonged ageing at 550° C. reduced the strength without improving E or ductility.

Conclusions

(1) The beneficial effect of carbon additions on the Young's modulus of titanium was confirmed. Room temperature E of rolled strips increased linearly at a rate of $1·4 \times 10^6$ lb./in.² or 8·75% for each 1%C added, which was intermediate between the rates calculated for alloys consisting of continuous lamellae parallel or perpendicular to the stress axis. Room temperature G rose $0·69 \times 10^6$ lb./in.² or 11·6% for each 1%C, and the average rate of increase of E at 400° C. was $1·8 \times 10^6$ lb./in.² or 17·3%/1%C added.

(2) To achieve parity in specific E with a ferritic stainless steel over the range 20–400° C., a carbon content of 2·5% is necessary. A binary alloy of this carbon content had E's of 19·4 and $15·7 \times 10^6$ lb./in.² at 20 and 400° C., but both strength and elongation were low (about 40 tons/in.² and 8%).

(3) Carbon is considered unlikely to be used as a modulus-raising addition in commercial sheet alloys unless its effect on ductility can be lessened. Reducing the size of the carbide particles would probably do this, but the only promising method of securing such a reduction involves recourse to powder metallurgy techniques.

(4) Surface cracking of hypereutectic titanium-carbon alloys during hot-rolling could be prevented by cladding with unalloyed titanium.

(5) Ternary alloys containing carbon and aluminium in amounts sufficient to give a significant improvement in modulus were brittle.

Acknowledgments

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The Deposition of Metals Other Than Those of the Titanium Group by the Hot Filament Technique

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THE deposition of a metal on an electrically heated filament by the decomposition of a volatile compound—the so-called hot filament technique—is prominent in the history of the incandescent lamp. It was originally used to obtain filaments of high melting point metals—first osmium, then tantalum, and later tungsten—and from these beginnings[1] came the iodide process of van Arkel and de Boer,[2] the application of the hot filament technique to the refining of the metals of the titanium group. The hot filament technique is best known under the name of the iodide process, and in the hands of van Arkel and de Boer it provided the first pure specimens of titanium, zirconium and hafnium, and led to a new appreciation of their properties. By this work the value of the technique was demonstrated to such purpose that from this time a not inconsiderable number of preparations of many other metals was carried out, or attempted, by this method. For the most part these metals could be obtained in a reasonable state of purity by conventional extraction processes, and their preparation by the hot filament technique has been obscured by the much more spectacular and exciting preparations of the metals of the titanium group. Generally, the information obtained from these other preparations added but little to the existing knowledge of the metals, and was as nothing compared with the rewriting of the mechanical and physical properties of titanium and zirconium which took place following the work of van Arkel and de Boer. Objectively, these preparations seem of little interest, and their obscurity deepens with the passage of time, yet they merit discussion for their intrinsic interest and as a facet of halide extraction metallurgy.

General Considerations

The deposition of metals by the hot filament technique may be carried out by either the *flow* method or the *sealed bulb* method. The former requires the vapour of a volatile compound of the metal to be passed over an electrically heated filament, either by entrainment with hydrogen or by the use of a pump, while the latter requires the continuous formation and decomposition of the volatile compound within the sealed apparatus. The essential difference between the two uses of the technique lies in the mode of removal of the gaseous product of the filament reaction. In the flow method it is pumped away or swept from the reaction site, and in the sealed bulb method it is removed by its reaction with the metal in the apparatus. Faster rates of deposition may be obtained with the flow method, but on account of its susceptibility to contamination by the atmosphere, the sealed bulb method is preferred where oxygen and nitrogen, even in very small concentration, cannot be tolerated.

The conditions for the use of the hot filament technique, though implicit in the early work on incandescent lamp filaments, were first clearly stated by Fischvoigt and Koref.[3] Referring to the flow method, and citing chlorides as the volatile compounds, they stated that "the considerations governing the choice of a metal to be deposited on the filament are, on the one hand, the metal must have a volatile chloride, and on the other, the metal must have a high melting point." Their experiments on the deposition of magnesium were abandoned because the second condition was not fulfilled. This statement may be rewritten to read with more significance :—

(*a*) The metal must form a volatile compound.

(*b*) The metal must have a melting point greater than the temperature of the filament reaction (i.e. the decomposition temperature of the compound or the temperature at which it is reduced by hydrogen).

Van Arkel[4] added the further condition with reference to the sealed bulb method :—

(*c*) The volatile compound must readily be formed from its elements at easily accessible temperatures.

Though adequately stated in these general terms, there is a vagueness about these conditions which cannot, however, be made more precise with respect to vapour pressures and filament temperatures. The transition elements are suggested as metals which may be deposited, for among them are to be found the metals of highest melting point, and many of them combine readily with the halogen elements to give covalent compounds characterised by their volatility. Other than these, the only true metal of an apparently suitably high melting point is beryllium, while it is noted that boron, carbon and silicon also meet the requirements. The description of the deposition of the various metals given below, in showing the ramifications of the hot filament technique, indicate the range of vapour pressures and filament temperatures necessary for the deposition of metal to take place, and provide a basis for a discussion of Fischvoigt and Korefs' conditions.

Deposition of Particular Metals

Vanadium

While some physical properties of vanadium may be found listed in the handbooks, a knowledge of its metallurgy is almost exclusively confined to its behaviour as an alloying element in special steels. It forms a stable nitride and carbide, and with oxygen gives a range of ordered intermediate phases up to the composition V_2O_3.[5] It is somewhat similar to titanium and zirconium in its behaviour towards carbon, nitrogen and oxygen, and the difficulties encountered in the extraction of these metals must be expected to apply to vanadium. Thus, Pearson[6] has reviewed the extraction metallurgy of

vanadium and concluded that metal suitable for research purposes—here the study of alloy systems, but we may include the determination of physical and mechanical properties—is obtained only in those processes which take place in the absence of nitrogen and oxygen. The most convenient method now in current use for preparing vanadium in useful quantities is the bomb reduction of vanadium pentoxide with calcium, but whether the resulting metal is free from oxygen is a matter for conjecture. There is little doubt that a supply of vanadium, free from non-metallic impurities, would provoke the dormant interest in this metal and probably give rise to advances parallel to those made in the study of titanium and zirconium during the last 20 years.

Vanadium, with a melting point of 1,750° C. and forming covalent halides, would seem a suitable subject for preparation by the hot filament technique, and its preparation has in fact been carried out by this method. Fischvoigt and Koref[3] used the flow method, in which the vapour of vanadium tetrachloride was entrained by hydrogen (probably at room temperature, although this was not stated) and led over the tungsten filament heated to an unspecified temperature. A polycrystalline deposit of vanadium was obtained. This method of preparation does not appear to have attracted further interest, due most likely to the fact that the work of Fischvoigt and Koref was severely criticised by van Arkel and de Boer[2] on the grounds that the hydrogen introduced considerable amounts of impurities into the deposited metal.

The preparation of vanadium by the sealed bulb method would thus seem to be more rewarding, and its preparation by the iodide process was reported by van Arkel.[7] This required an oven temperature of 800° C., i.e. the ambient temperature of the apparatus required to volatilise the iodide, and because of this the apparatus was made of silica. With this ambient temperature and a filament temperature of 1,000° C., a deposit of vanadium was obtained which was described as very ductile. No further details were published, and it is obvious that the relative lack of volatility of the iodide was the chief factor in limiting the preparation of the metal to quantities of the order of a few grammes, requiring as it did the use of silica apparatus with its attendant practical difficulties.

The failure of the iodide process to do for vanadium what it had done for titanium is thus to be found in the halide chemistry of vanadium, and emphasises the importance of studies of the complete metal-halogen equilibria, rather than a knowledge of the properties of the most readily accessible compounds. In contrast to titanium, vanadium does not give a range of halides corresponding with its group valency. Its maximum covalency is brought out in combination with fluorine, but with increasing size of the halogen the covalency decreases, so that the halides which may be prepared containing the maximum number of atoms of halogen per molecule are : VCl_4, VBr_3, and VI_3. These are formed from the elements when the halogen is in excess, but the halogen dissociation pressures over the pure compounds are so great that manipulation at elevated temperatures and reduced pressures leads to the formation of a lower halide, and this decrease in the number of halogen atoms in the molecule gives rise to a lower volatility. Thus, vanadium tetrachloride may be used for the flow method, but with some loss due to the deposition of vanadium trichloride within the apparatus, but vanadium tri-iodide cannot be used for the iodide process as, under the operating conditions and in the presence of an excess of vanadium metal, the stable species is the di-iodide.

Further details of the preparation of vanadium by the iodide process were given by Nash, Ogden, Durtchi and Campbell.[8] Their apparatus consisted of a Vycor bulb with graded glass tubulations enabling the electrodes to be sealed into the apparatus and allowing the bulb to be joined to the pumping system and iodine reservoir. The di-iodide was synthesised in the apparatus at 800-900° C., and with the temperature of the apparatus maintained in this range and a filament temperature of 1,400° C., quantities of vanadium of the order of 50 g. were obtained. The deposited metal rods were not of uniform cross section, but were polycrystalline with additional crystals projecting spine-like from the core. It was found that if the iodine set free in the filament reaction were continuously pumped from the apparatus, the deposited rod was much smoother, though still polycrystalline. The iodide vanadium was arc melted under argon at 10 cm. Hg pressure, and the buttons obtained were cold rolled to sheet of 0·04 in. thickness, representing 80% reduction, without intermediate annealing. This material was used for grain growth and recrystallisation studies.

Niobium and Tantalum

Unlike vanadium, and on account of a larger covalent radius, niobium and tantalum form a complete range of penta-covalent halides, and, possessing suitably high melting points (niobium 2,415° C. and tantalum 2,850° C.) they may readily be prepared by the hot filament technique. Von Pirani[9] used the flow method to prepare tantalum deposits, containing hydrogen, on platinum filaments by the decomposition of tantalum pentachloride in the presence of hydrogen. Fischvoigt and Koref[3] similarly obtained single crystal tantalum deposits on tungsten, and this method was also used by Moers.[10] The latter used both tantalum and tungsten wires as filaments at temperatures between 1,200° C. and 1,450° C., and reported very rapid rates of deposition; in one case the filament, originally 0·05 mm. diameter, reached a thickness of 2 mm. in about 15 minutes. In all these cases the interest was in the deposited metal, and the process of deposition was a means to this end. Thus, while Moers quoted filament temperatures as a necessary adjunct to the proper description of his deposit, the temperature of the tantalum pentachloride was not recorded. Burgers and Basart[11] used the method to prepare specimens of niobium and tantalum for lattice parameter measurements, and as the purity of the deposit was of the utmost importance, the chlorine set free in the filament reaction was removed by continuous evacuation to avoid contamination by hydrogen. The pentachlorides were sublimed *in vacuo* to free them from absorbed gaseous impurities, and the usual tungsten electrodes were replaced by nickel, nickel chloride being much less volatile than tungsten hexachloride, so avoiding the possibility of contamination by the co-deposition of tungsten. In the absence of hydrogen the filament temperatures were greater—1,800° C. for niobium and 2,000° C. for tantalum—and thin wires of the two metals were used as filaments, the heating effect of the filament sufficing to maintain suitable vapour pressures of the chlorides once the deposition had commenced. The rates of deposition were smaller than those observed by Moers, five hours being required for a deposit of tantalum

1·25 mm. thick, but suitable specimens were obtained, and in addition to the lattice parameter measurements, the specific resistance and temperature coefficient of resistance between 0 and 100° C. were measured for tantalum. From a consideration of the values obtained for different specimens, Burgers and Basart concluded that the vacuum sublimation of the penta-chlorides was a necessary step towards obtaining deposits of the highest purity.

The number of examples of the preparation of tantalum suggest the ease with which this metal is deposited. In view of the corrosion resisting properties of these metals, it is not surprising that the process has been suggested and used for the deposition of protective coatings of tantalum and niobium on various materials.[12] The main drawback in the application of such a process lies in heating objects of non-regular shape to uniform surface temperatures, and of possible unwanted structural changes in the material arising from heating to the deposition temperature.

Chromium

An attempt was made by Pring and Fielding[13] to deposit chromium on an electrically heated carbon rod by the decomposition of chromyl chloride in the presence of hydrogen; this resulted in an explosion. The chlorides are insufficiently volatile at temperatures up to the softening point of glass to allow the flow method to be used, but chromium may be deposited by the iodide process under conditions similar to those required for vanadium. Van Arkel[14] gave the conditions for the iodide process as requiring a temperature of 800° C. to volatilise the iodide and a filament temperature of 1,100° C., and indicated that the metal so obtained was ductile. The enigmatic nature of the hardness of chromium has promoted much interest in the preparation of the metal in a high state of purity, and among the methods used is to be found a revival of the iodide process. Goodwin, Gilbert, Schwartz and Greenidge[15] used the method to obtain specimens for plasticity studies, and although no details were given of the conditions for deposition, it may be assumed that they were substantially the same as those of van Arkel. The deposited metal consisted of several hundred small crystals in the form of distorted octahedra, each adhering to the filament at one corner or at an edge, and in this form only limited tests could be made without consolidating the metal by melting. Individual crystals were removed from the deposit and compressed, and the slip bands observed were taken as evidence of the ductility of the metal.

Tungsten and Molybdenum

The halides of tungsten and molybdenum are more volatile than those of chromium, and this generalisation follows the relationship found between the halides of vanadium, niobium and tantalum. The chlorides $MoCl_4$, $MoCl_5$ and WCl_6 and the oxychlorides MoO_2Cl_2, WO_2Cl_2 and $WOCl_4$ have been used for the hot filament deposition of these metals, although the deposition of tungsten has received by far the most attention, on account of its candidature for use as an incandescent lamp filament material, and its subsequent availability as a filament material. With the exception of the metals of the titanium group, the conditions for the deposition of tungsten have been recorded in greater detail than for any other metal.

Just and Hanamans' use of the oxychlorides involved the reduction of these compounds with hydrogen on a carbon filament: this and their later use of tungsten hexachloride, and Pring and Fieldings' deposition of molybdenum and tungsten on an electrically heated carbon rod, have previously been discussed in tracing the development of the iodide process[1] and require no further comment. Koref's flow method[16] and van Arkel's sealed bulb method[4] stand, however, as classic examples of the hot filament technique, giving in addition an insight into the deposition process. Koref indicated that in the flow method the morphology of the deposit was related to the rate of deposition, which, in turn, was controlled by the partial pressures of tungsten hexachloride and hydrogen. Van Arkel discussed the influence of the filament temperature and the orientation of single crystal filaments on the deposition of single crystals, and made further observations relevant to any deposition by a sealed bulb method. He pointed out that working with increasing vapour pressures of tungsten hexachloride required increasingly greater filament temperatures, and that the requirement necessary for continuous deposition was to keep the partial pressure of the free chlorine in the apparatus to as low a value as possible. This may readily be deduced from a mass action interpretation of the filament reaction, yet these vital statements are often insufficiently appreciated. Indeed the successful preparation of any metal by the sealed bulb method depends on the presence of an excess of the metal to remove the halogen, ideally as fast as it is formed: without this excess metal no deposition occurs.

Rhenium

Following the discovery of rhenium in 1925, the element was first isolated as the metal powder, and Noddack was able subsequently to prepare the metal in a compact form by making use of the hot filament technique.[18] The high melting point of the metal—3,400° C.—and the volatility of the chloride obtained by chlorination of the metal powder enabled the flow method to be used. The dark green chloride (reported by Noddack as the heptachloride but probably the tetrachloride[18, 19]) was synthesised in the apparatus from the elements at 50–100° C. and excess chlorine was removed with the pump, which also served to remove the chlorine set free in the filament reaction. Deposition took place with the platinum filament heated to 800° C., while at filament temperatures in the range 1,000–1,200° C., the deposition was so rapid that the filament could be seen increasing in size. The method was further used by Moers and his colleagues,[20] who found that the tribromide could be decomposed in like fashion, as well as the volatile oxide Re_2O_7 when entrained with a hydrogen/nitrogen gas mixture.

Iron

Among the metals which Fischvoigt and Koref deposited by the flow method on tungsten single crystals is to be found iron. Ferric chloride was used as the volatile compound, and at filament temperatures above 910° C. polycrystalline deposits were obtained, while below this temperature, in the range of α-iron, a single crystal was deposited.

Van Arkel carried out the preparation of iron by the iodide process.[7] The elements combined together in the apparatus at about 300 °C. and maintaining this tem-

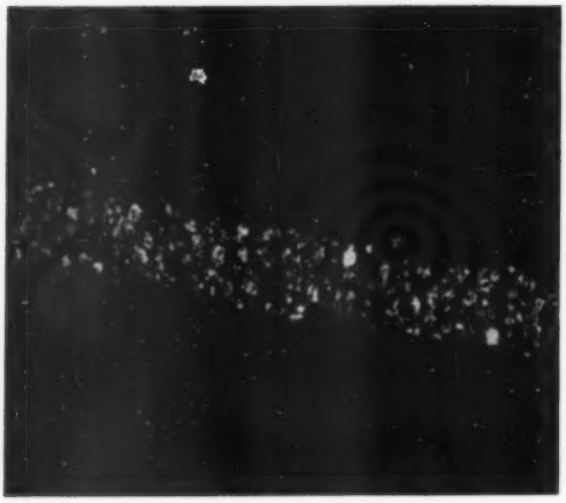

Fig. 1.—Deposit of iron produced by the iodide process with an ambient temperature of 300° C. and a filament temperature of 900° C. × 7

perature with the filament at 900° C., iron was deposited. The metal was reputedly free from carbon, but further details of the deposition or the deposited metal were not given. Fig. 1 shows a deposit of iron obtained under these conditions. In view of the interest shown at various times in the plastic behaviour of high purity iron, it might be thought surprising that so little use appears to have been made of this method of preparation. Considering, however, that the metal as deposited is not in a suitable form for immediate use further hot working or melting would give such an uncertainty of composition with respect to non-metallic impurities that the advantages derived from the use of the hot filament technique as a refining process would largely be nullified.

Osmium

The deposition of osmium by Welsbach in about 1898 is mainly of historic interest as representing one of the first attempts to prepare a metal filament for use in the incandescent lamp. The flow method was used: the volatile osmium tetroxide was decomposed on a carbon filament, carbon and oxygen being eliminated as carbon monoxide so that a filament of osmium remained. In this case, as in the decomposition of tungsten and molybdenum oxychlorides on carbon filaments, the filament plays an essential chemical role in the process, in addition to providing the reaction site. The deposition reaction must proceed to a conclusion when all the carbon of the filament is consumed, and at a rate which is controlled by inter-diffusion of the deposited metal and carbon. In these cases it would not be expected to obtain extensive deposition of metal.

Platinum

The hot filament technique was used by Reerink[21] to separate platinum from iridium, rhodium and palladium. This work used volatile compounds of a type different from those met with so far, namely the platinum carbonyl chlorides. Dry carbon monoxide was passed over asbestos impregnated with a mixture of the chlorides of these metals, and on heating, the volatile platinum compounds, $Pt(CO)_2Cl_3$, $(PtCl_2)_2(CO)_3$, $PtCOCl_2$ and $PtCl_2(COCl_2)_2$ were formed. On passing over a filament heated to 600° C. a deposit of platinum in a compact form was obtained, the volatile products of the reaction, carbon monoxide, chlorine and carbonyl chloride, being removed by pumping. In this case the deposited metal is not susceptible to contamination by carbon and oxygen, and its purity was indicated by the value of its temperature coefficient of electrical resistance.

Copper

Copper may be deposited by the iodide process, van Arkel[14] briefly stating that an oven temperature of 400° C. and a filament temperature of 900° C. are required. As far as the refining or deposition of copper is concerned, this method has no advantages over the conventional processes, but it is an interesting addition to the list of metals which may be deposited by the hot filament technique. Cuprous iodide, with a melting point of 602° C., does not typify a volatile compound, and the melting point of copper does not place it in the same category as the metals dealt with so far. However, it is apparent that the vapour pressure of the iodide is sufficiently high so far below its melting point for the deposition to take place. Fig. 2 shows a specimen of copper deposited by the iodide process, the dendritic mass being quite different in appearance from most other metals prepared in this way, lacking the highly developed crystalline form which is usually a characteristic of the iodide process.

Beryllium

The remaining true metal with a melting point greater than 1,000° C., beryllium (1,284° C.) represents an interesting case. In spite of the fact that beryllium is strongly electropositive, its halides are volatile due to the extreme deformation of the halogen by the small and highly polarising beryllium ion, thus conferring a high degree of covalent character on these compounds. Beryllium chloride has a melting point of 410° C. and a boiling point of 488° C.; beryllium iodide melts at 480° C. and also has a boiling point of 488° C., the narrow temperature range of the liquid indicating a relatively high vapour pressure over the solid state. It would thus seem that filament temperature and vapour pressure conditions for the preparation of beryllium by the hot filament technique might be satisfied for both the sealed bulb and flow methods.

The preparation of beryllium by the iodide process was in fact attempted by Rosenhain, Vivian and Sloman[28] in 1932, and that this attempt failed was not due to the proximity of the decomposition temperature of the iodide to the melting point of the metal, but to the unforeseen extreme reactivity of the iodide. The iodide was synthesised from its elements in the apparatus in the temperature range 350–450° C., and deposition took place with the filament heated to a temperature in the range 700–900° C. During the deposition, however, the glass reaction vessel became opaque and the filament, which had grown to 1–3 mm. in thickness, was brittle and contained much silicon and boron. These latter had arisen from the reaction of beryllium iodide with the glass of the reaction vessel. The great affinity of beryllium for oxygen, as seen in the stability of its oxide and the tendency in its aqueous solution chemistry to form the so-called basic salts, causes beryllium to leave its

unfamiliar halogen environment and react with silicon-oxygen and silicon-boron units in the glass, thereby giving rise to volatile silicon and boron compounds which are decomposed on the filament. The attack on the glass was so severe that the experiments were discontinued.

Hackspill and Besson,[23] using the flow method, attempted the deposition of beryllium by means of the decomposition of beryllium chloride with hydrogen, on tungsten, nickel and iron filaments. The filaments, heated to temperatures in the range 1,000–1,500° C., vaporised the beryllium chloride in the filament chamber while hydrogen was passed through the apparatus. Some deposition took place, but this was invariably followed by fusion of the filament, which is perhaps not surprising considering that the upper half of the filament temperature range lies above the melting point of beryllium. The fusion of the filament at temperatures below the melting point of beryllium was attributed by Hackspill and Besson to the formation of alloys above their solidus temperatures.

Uranium

With a melting point of 1,133° C., the deposition of uranium would seem to be feasible provided the availability of a compound of suitable volatility. Uranium tetra-iodide, which is formed from its elements when iodine is in excess, appears to be sufficiently volatile, but under the conditions required for the iodide process, i.e. the presence of an excess of the metal, the stable compound is the tri-iodide, which is not sufficiently volatile to sustain the filament reaction. The pattern of behaviour noted with vanadium appears to be repeated here, and while Prescott, Reynolds and Holmes[24] found that a straightforward application of the iodide process was not possible, they were nevertheless able to deposit uranium on tungsten filaments in a modification of the iodide process, arrived at from a consideration of the equilibria between uranium, iodine and uranium iodides. Uranium tri-iodide combines with iodine to give the tetra-iodide, which may be volatilised as long as iodine vapour is present. and hence decomposed on the filament. The decomposition of the tetra-iodide takes place in two ways—to give uranium and iodine, and to give uranium tri-iodide and iodine, the latter being unproductive in the deposition of uranium. Thus they proposed to place uranium tri-iodide in the apparatus, in place of the metal, and to obtain an overall transfer from the charge to the filament by the sequence :—

$$2UI_3 + I_2 \rightarrow 2UI_4$$
$$UI_4 \rightarrow U + 2I_2$$

The equations indicate that as a result of the deposition of uranium on the filament, the partial pressure of iodine within the system increases, so that a reaction between iodine and the deposited uranium may subsequently take place, effectively stripping the filament of its deposited metal. By working with an iodine reservoir, the temperature of which could be controlled independently of the ambient temperature of the apparatus, a critical vapour pressure of iodine was found below and above which deposition of uranium or stripping of uranium from the filament took place, for a range of filament temperatures and ambient temperatures. These experiments led to the evaluation of the equilibrium constants and hence the free energy changes for the various equilibria involved, and a set of conditions was formulated for the steady deposition of uranium on the filament. To deposit uranium at filament temperatures in the range 1,030–1,100° C. required the uranium tri-iodide at 500–530° C. ; the iodine reservoir at such a temperature as to give a vapour pressure of iodine of 7×10^{-3} mm. Hg (about − 40° C.) ; and a bulb temperature of 520–560° C. (to prevent tri-iodide from the unprofitable filament reaction from condensing on the walls of the bulb). The metal so obtained was pure, with a silvery metallic lustre similar to platinum, and slowly oxidised on exposure to the air. The quantities of uranium prepared in this way were apparently quite small, and although, as so often observed, this method is palpably unsuitable as a production process, the work brilliantly underlines the importance of metal-halogen equilibrium studies, for only by the application of such knowledge was this apparently impossible deposition carried out.

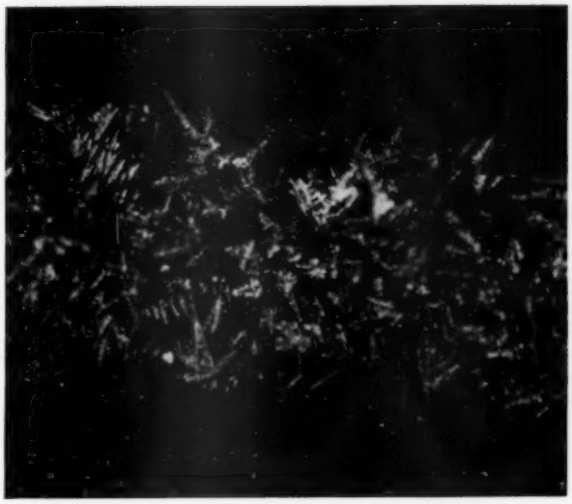

Fig. 2.—Deposit of copper produced by the iodide process with an ambient temperature of 400° C. and a filament temperature of 900° C. × 7

Examination of the Conditions for the Hot Filament Technique

An attempt may be made to amplify the considerations of Fischvoigt and Koref and van Arkel by examining those features which are common to all these depositions. This is best carried out under the separate headings of the flow method and sealed bulb method, but it may be said immediately that from the aspect of the practice of the hot filament technique the term " volatile compound " is of significance only when stated in relation to the material which is available for the construction of the apparatus. Thus, in the sequence Pyrex glass—Vycor—silica, such a range of ambient temperatures may be covered that the formal lack of volatility of a particular compound has been seen to have been merely an impediment to the preparation of a metal, and not an insurmountable difficulty.

The Flow Method

Types of Compound

The examples of the flow method show that the compounds which have been used are not limited to the

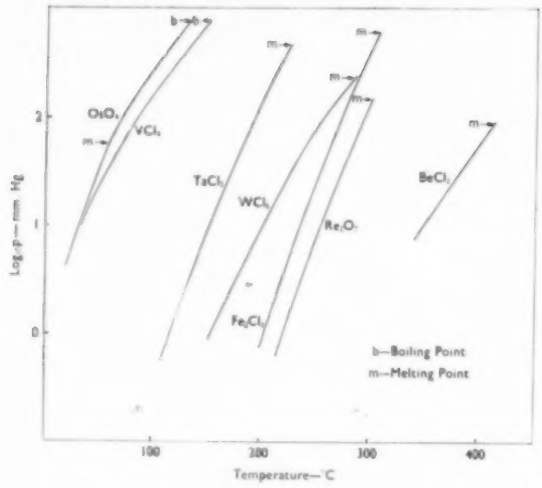

Fig. 3.—Vapour pressures of some compounds used in the flow method.

chlorides. They range from chlorides through oxychlorides to oxides, and by adding the examples of the carbonyl processes there is a further sequence from chlorides through carbonyl chlorides to carbonyls; these series roughly correspond to the positions of the metals in the periodic classification. There appear to be no records of the use of organo-metallic compounds, which however, would probably be of use only for those metals which do not form stable oxides and carbides.

Vapour Pressures

The vapour pressures of some compounds which have been used in the flow method are shown in Fig. 3, where $\log_{10}p$ mm. Hg is plotted against temperature, the source of the data being Kubaschewski and Evans' "Metallurgical Thermochemistry."[25] It is not possible to estimate vapour pressures for the various depositions due to the lack of information on the temperature of the compound. In many cases the compounds were volatilised by placing them within the apparatus in the proximity of the filament, and even in those cases where an ambient temperature has been stated, in view of the unknown pumping rates and flow rates of hydrogen, there is additional uncertainty as to whether the saturated vapour pressure of the compound is reached. There is, however, one exception, and this is to be found in the work of Koref, where he states that with the tungsten hexachloride reservoir at 250° C. and hydrogen flowing through the apparatus at atmospheric pressure, tungsten is obtained as a porous dendritic deposit, while a single crystal deposit is obtained with the reservoir at 110° C. and a total pressure in the apparatus of 12 mm. Hg. The saturated vapour pressure of tungsten hexachloride at these ambient temperatures is about 96 mm. Hg and 0·5 mm. Hg, respectively, the latter being an extrapolated value. The two sets of conditions, with the rapid deposition in the first case and the slow and steady growth of the single crystal in the second, would seem to approximate to upper and lower limits, so that it may be estimated that the flow method requires the volatile compound to have a vapour pressure of the order 10 mm. Hg. Whether or not the deposition is carried out with a vapour pressure higher or lower than this will depend on the total pressure in the system, the rate of flow, and the filament temperature. The data of Fig. 3 support this as a reasonable estimate, where it is seen that vapour pressures of this order of magnitude of the compounds used in the various depositions are readily obtained with the glass apparatus used.

Filament Temperatures

While filament temperatures for deposition from chlorides as low as 900° C. for iron and 800° C. for rhenium are reported, the general range of filament temperatures appears to be from 1,200–2,000° C. The filament temperature required will vary greatly from one type of compound to another, the relatively low temperature of 600° C. used for the decomposition of the platinum carbonyl chlorides and the still lower temperatures used in carbonyl processes indicating this variation, which is in accord with the accepted views of the stability of these compounds. Even within a group of similar compounds there will be considerable variation, and in the absence of the relevant thermochemical data it is not profitable to speculate further on the filament temperatures required for deposition by the flow method. It may be added, however, that in any deposition a decrease in the partial pressure of the compound will enable a lower filament temperature to be used, but the use of this as a means to bring the deposition temperature below the melting point of the metal may result in such a slow filament reaction that no sensible amount of deposit is obtained.

Sealed Bulb Method

Compounds

Because of the requirement that the gaseous product of the filament reaction must combine with an excess of the impure metal, halides are the only possible compounds which may be used in the sealed bulb method. The dissociation of the chloride on the filament takes place at a higher temperature than the reaction in the presence of hydrogen, and it is evident that in only those cases of metals of melting point greater than about 2,000° C. is the dissociation temperature of the chloride exceeded by the melting point. Thus, the chlorides of metals of lower melting point than this would not be expected to be of use, and the logical development of this argument led to van Arkel's use of iodides, with their lower dissociation temperatures, and gave rise to the iodide process. The sealed bulb method is thus to be particularly associated with iodides, and is discussed from this standpoint.

Vapour Pressures

In contrast to the findings for the flow method, the ambient temperatures used in the iodide processes are given in the literature, and it may reasonably be assumed that the vapour pressures of the compounds correspond with the saturated vapour pressures at these temperatures. The vapour pressure data of iodides is scant, but those which are available are shown in Fig. 4. The data, which include titanium tetra-iodide for comparison, are from the previously mentioned source, with the exception of chromous iodide, which is that given by Allen.[26] The optimum conditions for the deposition of titanium from titanium tetra-iodide obtain with an ambient temperature of about 170° C., corresponding to a vapour pressure of about 5 mm. Hg, but deposition

TABLE I.

Metal	Melting Point (° C.)	Filament Temperature (° C.)	Vapour Pressure at Filament Temperature (mm. Hg)
Beryllium	1,284	900	7×10^{-4}
Titanium	1,725	1,400	1×10^{-4}
Vanadium	1,750	1,400	5×10^{-5}
Chromium	1,860	1,100	5×10^{-4}
Copper	1,083	900	7×10^{-5}

will occur with an oven temperature as low as 50° C.[27] when the tetra-iodide vapour pressure is much less than 1 mm. Hg. The attempts to deposit beryllium used ambient temperatures in the range 350–450° C. with vapour pressures of beryllium iodide between 10 and 100 mm. Hg, while extrapolation of the chromous iodide curve to 800° C. gives a vapour pressure of 2 mm. Hg for the deposition of chromium. For the deposition of copper, in which the oven temperature is 400° C., the vapour pressure of cuprous iodide is certainly less than 5 mm. Hg, and probably about 1 mm. Hg. It would thus appear that the vapour pressures in the sealed bulb method are significantly smaller than those in the flow method, which may be reconciled with the kinetics of the two systems consequent on the difference in the mode of removal of the halogen from the reaction site. Given that the conditions of filament temperature and reactivity of the raw material are satisfied, it is estimated that a vapour pressure of the compound of the order 1 mm. Hg suffices for the deposition of a metal by the iodide process.

Filament Temperatures

The filament temperatures used in the iodide processes are shown in Table I. These have presumably been used with the intention of obtaining the fastest possible rates of deposition (with, perhaps, the exception of iron), consistent with the avoidance of the melting or evaporation of the deposited metal from the filament. While it is possible that deposition may occur at lower filament temperatures by the use of lower ambient temperatures, and hence lower vapour pressures, it is to be noted that, with the exception of copper and the rather special case of uranium, the metals which have successfully been deposited by the sealed bulb method have melting points greater than 1,500° C., and for all metals the filament temperatures do not appear to exceed a value at which the vapour pressure of the metal is greater than about 10^{-3} mm. Hg.

Conclusions

In conclusion, it may be said that the preparations described here fully explore the hot filament technique for metals other than those of the titanium group, and of all these examples, only vanadium and beryllium appear to be of present importance. The advances in technique which employed graded glass seals and Vycor reaction vessels have resulted in an ability to prepare quantities of pure vanadium which, though small, are by no means negligible for use in alloy research work, and if the failure of the iodide process for beryllium is to be attributed only to the reactivity of the iodide, a material other than glass for the construction of the apparatus might well lead to a successful deposition of this metal. It would thus seem that only in these directions is the hot filament technique likely to continue in use as a preparative method.

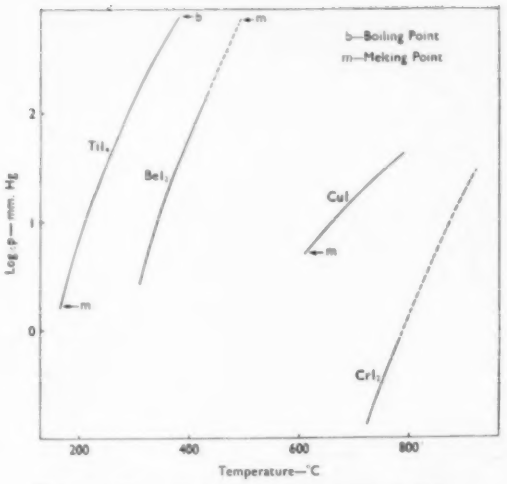

Fig. 4.—Vapour pressures of some iodides.

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Spark-Machining Film

THE rapidly developing technique of spark-machining is the subject of a new 16 mm. colour film, "The Wickman Erodomatic," produced by Wickman, Ltd., of Coventry. The film, which runs for about 17 minutes, begins with an animated sequence showing the nature of spark-machining, and illustrates the equipment necessary for the process with a description of the two Erodomatic models currently available. The next sequence gives a full demonstration of the operations necessary for a typical job, the production of a die for gas tap bodies, and underlines this demonstration with a sequence showing the main points of the production of a die for spoon handles.

Further production examples, including the drilling of 0·008 in. holes in hardened steel ball bearings and deep holes in Nimonic 90, conclude the film, which was shown for the first time at a lecture before the Institution of Production Engineers, at the Grand Hotel, Sheffield, on November 11th. It will be shown at the Borough Polytechnic, Borough Road, London, on December 17th, and copies of the film, which carries a fully descriptive commentary, will be available for loan in the near future; a companion booklet is in course of preparation.

Boiler house building.

Power Plant for Titanium Production

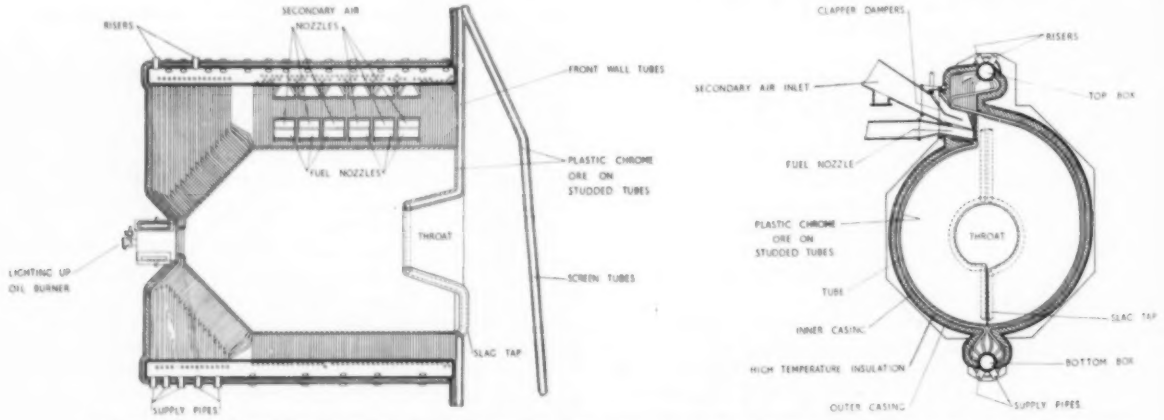
New Cyclone Fired Boiler at I.C.I. Metals' Kynoch Works

SOME three years ago, the decision to instal a titanium melting plant at the Kynoch Works of I.C.I. Metals Division made it imperative to increase output from the works power station. Severe limitations were placed on the power engineers' choice of new plant, not only by space limitations but also by the fact that the works are in a partially residential area. The extra boiler and generator needed had to be extremely powerful for their size and to operate with a minimum emission of smoke and dust.

General Considerations

The boiler was required to have a 200,000 lb /hr. capacity, and four methods of firing were considered, namely chaingrate stoker, spreader stoker, pulverised fuel, and Cyclone. With the coals likely to be available, experience suggested a burning rate of 15–20 lb. of coal per square foot of grate area per hour with stoker firing, which would involve a grate area of prohibitive size. The choice lay, therefore, between pulverised fuel and Cyclone firing. In considering their relative merits, a not inconsiderable factor is that Cyclone firing is, in general, cheaper than conventional pulverised fuel firing, particularly if the electrostatic precipitation can be omitted. Furthermore, the Cyclone has very great advantages over pulverised fuel firing in relation to dust emission and size.

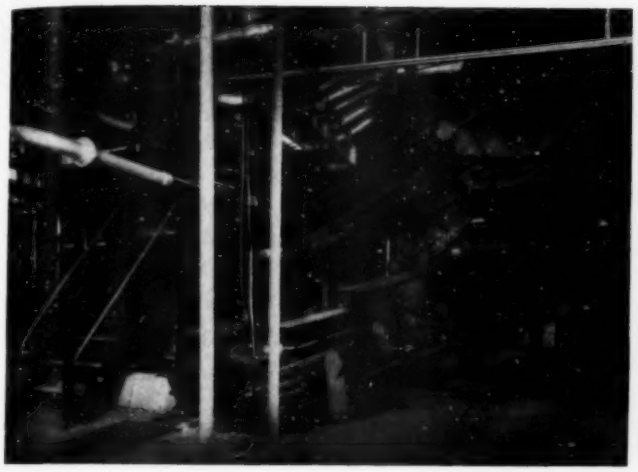
The eventual choice was, therefore, a Babcock and Wilcox Cyclone fired boiler which has now been in operation about a year. Designed and constructed in two years, the new unit represents a major advance in the technique of steam production in the United Kingdom, although many boilers fired in this way are in operation in Germany and the U.S.A. The Kynoch boiler has operated consistently at an efficiency of slightly under 90%, and may be claimed to be one of the most efficient boilers in this country. Furthermore, although this boiler will operate satisfactorily on coal of such low



(a) Longitudinal section through vertical centre line.

(b) Transverse section through fuel nozzle.

Typical Cyclone furnace.



General view of slag extraction plant in basement.

Cyclone viewed from firing floor.

quality as virtually to prohibit its use on conventional plant, the ash disposal problem is completely solved, the ash being produced in the form of granular slag, readily usable on civil works. Fly-ash disposal, a very serious matter with pulverised fuel-fired boilers, is eliminated. A specification for a satisfactory fuel would probably be as follows : a free burning coal having an ash content of not less than 6% and an ash fusion temperature not higher than 1,400° C. to produce a slag of reasonable viscosity. The indications are that any coal having a silica ratio of under 70% is satisfactory. Experience to date does not allow of an assessment of the behaviour of coals which have given trouble in respect of bonded deposits.

The increase in efficiency is in the main due to reduction of flue gas losses. Modern conventional coal burning plant needs approximately 25% more air than is theoretically necessary to provide satisfactory combustion, whereas the Cyclone-fired boiler, with its intimate mixing of air and fuel, operates most efficiently on about 8% excess air. This considerably reduces the weight of gas being discharged from the stack, and hence, assuming a comparable gas temperature, gives a corresponding reduction in energy loss.

The Kynoch Boiler

The raw coal is coarsely pulverised in a beater mill before being borne on an inert gas stream to the coal dust separators, and thence into the pulverised fuel storage bin. From the storage bin, the pulverised coal passes to the Cyclone combustion chamber through four variable speed feeders, the speed of which closely controls the quantity of coal fed, and hence the boiler output.

The Cyclone furnace is a cylindrical chamber, which may be set at a slight angle to the horizontal, in the front of a radiant furnace, and communicating with it by a re-entrant throat. It comprises a series of closely-pitched water-tubes of which the inner surfaces are covered with chrome-ore refractory, and the outer surfaces by an insulated steel casing. These tubes are connected to inlet and outlet headers which form part of the natural circulation system of the boiler. Once in the Cyclone, the coal stream meets a high-velocity, tangential stream of pre-heated (600° F.) secondary air and combustion takes place with extreme rapidity due to the scrubbing action of the secondary air. The high temperature generated causes the ash particles to melt and, under centrifugal force, the molten ash clings to the wall of the Cyclone, from which it flows into the secondary chamber, thence to the ash quenching tank in the basement.

After passing through the Cyclone throat, the high temperature gas is now deflected downwards by the target wall, then upwards through the staggered tubes of the slag screen, where the last remaining droplets of molten ash are trapped. About 8% of the ash passes through the slag screen as microscopic dust, to be later collected in the air heater passes, and finally in the electrostatic precipitator. On test, the dust burden of the exit flue gas was 0·033 grains per cubic foot, or less than 10% of the generally accepted standard of dust emission. This dust can be mixed with the coal feed and melted in the Cyclone.

After the slag screen the boiler is of Babcock and Wilcox " Radiant " design giving final steam outlet conditions of 925 p.s.i., 915° F., with an output of 200,000 lb./hr. An interesting feature of the construction is that the front wall enclosing the Cyclone throat, and the Cyclone itself, were prefabricated and erected as single units—possibly the first instance in this country of this increasingly popular method of construction.

Auxiliary Plant

The main and auxiliary fans, supplied by Davidson & Co., Ltd., are driven by Mather and Platt 3·3 kV. direct-on-start motors controlled by Metropolitan-Vickers type VH oil circuit breakers. The F.D. Fan is of special interest in that it generates 40 in. w.g. at the inlet to the Babcock tubular air heater.

The boiler is fitted with fully automatic control by

Combined steam and electrical control room.

George Kent, Ltd. The fuel/air ratio is initially obtained by both total air flow and fuel controllers being set by the main impulse from the master pressure controller; a unique addition to the system is the final control of the fuel/air ratio by a measurement of excess oxygen in the flue gas. The flue gas is continuously and automatically analysed, the analyser putting out a signal proportional to the oxygen content of the gas. The feeder speeds are controlled by a main impulse from the master pressure controller, biased by the oxygen controller signal and finally corrected by a closed loop impulse from the total fuel transmitter, this latter being proportional to the summation of the speeds of all operating feeders. The total fuel transmitter impulse is fed into the total fuel controller, where it is continuously compared with the combined pressure controller and oxygen analyser signals. Dual air compressors are installed, but should these fail, the Kent-Lockheed "Hydrolock" system locks all controls in their instantaneous position, where they remain until taken over by the manually operated hydraulic controls.

The control panel, designed by I.C.I., is of the flow type with full-size instruments inserted directly into a coloured diagram. This arrangement takes up rather more than normal panel space, but the experiment has been fully justified by subsequent operational experience.

Power Plant

The Cyclone boiler supplies steam to a Metropolitan-Vickers 6·5 MW. back-pressure turbo-alternator, supplying power to the works system at 6·6 kV. After expansion through 12 single-impulse stages, the steam exhausts from the turbine at 235 p.s.i.g., thus acting as a "topping set" on the range of 225 p.s.i. Babcock and Wilcox C.T.M. boilers of the previously existing power plant, bringing the total station output to 28·5 MW.

This turbo-generator is fitted with automatic load and back-pressure controls. It can be operated independently with these controls disconnected; in parallel with a substantially constant frequency system with the controls connected or disconnected, or in parallel with other sets, either the load or back-pressure being maintained by the corresponding controls.

Advantages of Cyclone Firing

The Cyclone fired boiler is essentially a high efficiency steam raising unit in which the problem of ash disposal without grit emission is solved by melting the ash to a slag which can be granulated and sold. Advantages claimed for this type of boiler—several of which have already been mentioned—are summarised below:—

(1) Smaller overall size than the normal pulverised fuel unit.
(2) A minimum of ash dust passing through the boiler.
(3) 90% of the ash in the coal removed from the unit in handleable and nuisance free form.
(4) Slag saleable.
(5) Extremely small dust emission from chimney.
(6) Grit from the precipitators can be re-fired and removed with the rest of the slag.
(7) Intimate mixing of air and fuel in the Cyclone giving: (*a*) low carbon loss; and (*b*) low gas loss.

In an efficiency guarantee test on the Kynoch boiler, a heat account based on the gross calorific value showed a gross efficiency of 88·1%, the sources of loss being: dry gas—3·69%; moisture—5·37%; combustible in slag—0·02%; combustible in grits—nil; slag tank quenching—1·32%; and radiation and unmeasured (assumed)—1·5%. The efficiency of combustion is shown by the low figures for losses due to combustibles in slag and grit.

Laboratory Comes of Age

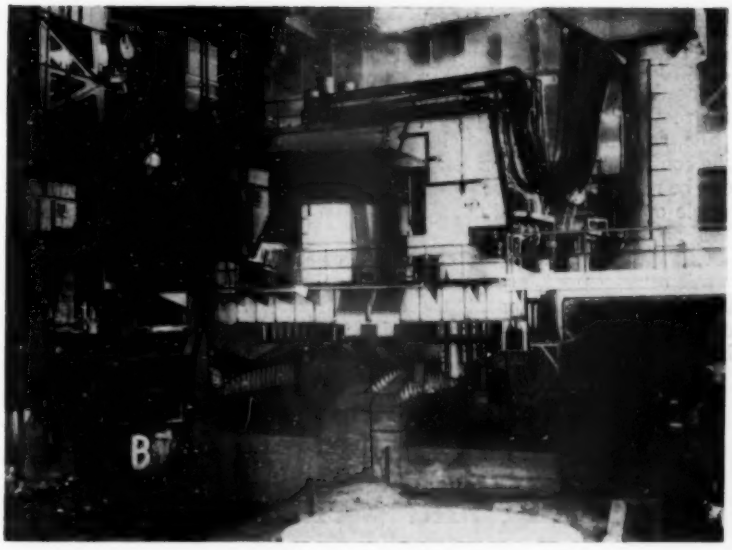
On Monday, October 21st, the Laboratory of the Development and Research Department of The Mond Nickel Co., Ltd., celebrated its 21st anniversary. The Laboratory, which is situated in Birmingham, was opened in 1936 by Lord Weir. At that time it had a staff of sixteen, under the direction of Dr. L. B. Pfeil, O.B.E., F.R.S., and was the most modern of its kind in Europe. To-day, the staff numbers over 180 people.

In the past twenty-one years, the Laboratory, which is devoted to the study of nickel and its alloys, has been responsible for the development of many new and valuable alloys, particularly the Nimonic series of high temperature materials, which enabled the theory of the gas turbine to become a practical reality, but also including alloys having a wide variety of other purposes in the chemical and electrical engineering fields. The members of the Laboratory have also played an important part in the development of the new type of cast iron known as spheroidal graphite cast iron, and they have also contributed many papers on the various theoretical aspects of metals, particularly transformations in special alloy steels.

The Laboratory celebrated its anniversary by holding a dance at the Grand Hotel, which was attended by the Chairman and Directors of the Company, by representatives of the various plants of The Mond Nickel Company, and also all members of the Laboratory staff. During the evening, the present Superintendent of the Laboratory, Dr. W. Steven, presented a silver cigarette box to the original Superintendent of the Laboratory, Dr. L. B. Pfeil, who is now a Director of the Company.

South Africa's First Large Arc Furnace

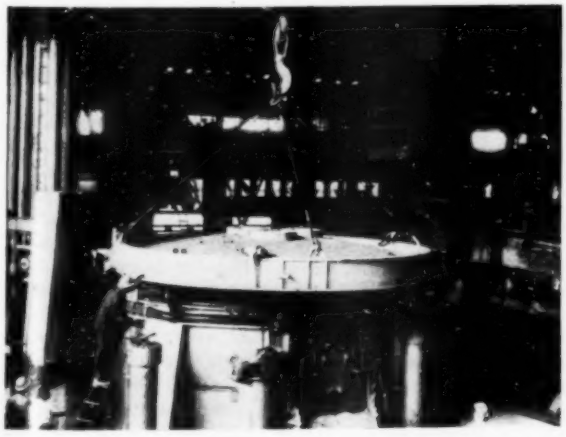
EFCO Plant Commissioned at Pretoria



General view of the installation.

THE first large electric arc furnace in the southern hemisphere was commissioned recently, when a 70-ton EFCO arc furnace went into operation at the Pretoria Works of the South African Iron and Steel Corporation in Transvaal. In the face of world-wide competition, the order was placed with Messrs. D Drury & Co , Ltd., of Johannesburg, formerly the exclusive agents in South Africa of Electric Furnace Co., Ltd., and now partners with the latter company in EFCO (South Africa) (Proprietary), Ltd. The furnace was built in South Africa to the design of the Electric Furnace Co., Ltd., of Weybridge, U.K.

It is a top charged, direct arc, tilting furnace with three 18 in. diameter graphite electrodes connected to a 15,000 kVA. transformer. The transformer is fed from a 33 kV supply and is fitted with " on-load " tap changing. The furnace shell has an inside diameter of 18 ft. 6 in., giving a nominal capacity of 70 short tons. Tilting of the furnace is operated hydraulically, and the maximum angles of tilt are 40° forward and 15° backward.



Lowering a new roof into position.

On starting up, the furnace was immediately put on to a 24-hour, seven days a week schedule, and in the month of September, 6,800 tons of steel were made. The average power consumption to date is under 500 kWh/ton, and the electrode consumption, under 8 lb./ton of steel melted.

Some details of the furnace design may be of interest The furnace bottom is flat and supported on a robust chassis. This simple construction makes bricking of the lining easier, and will facilitate the fitting of the non-magnetic steel plate to the furnace bottom, should an induction stirrer be required at a later date.

The body itself is entirely independent and sits on the chassis. It is made of skeleton construction, enabling the body plate, side panels and base panels to have " breathing " joints to cater for expansion, thus considerably reducing the risk of body distortion. These side panels are comparatively light, tack-welded plates, the use of which has been made possible by the sturdy main framework of the furnace. They can be removed for local lining repair from outside the furnace, and while it is still hot.

The back frame supporting the electrode raising gear and roof slew gear are entirely independent, thus avoiding the transference of torque or stress to the furnace body ; even with body distortion or roof ring distortion, there can be no interference with roof slewing. Only the roof ring and brickwork are lifted by the system of levers when raising and slewing, thus simplifying the supporting of the cantilever load, the massive weight of the roof being carried on a pivot post and suitably mounted rollers at platform level. The mechanical effort required for movement is considerably less than that required in designs where the whole of the back structure and electrode mast have to be lifted. The gallows type of electrode mast and arm is used in this unit, permitting the electrical conductors to be carried well above the steelwork, improving the overall power factor and reducing heating of the steelwork by eddy currents.

Roof changing is very simple. It is not necessary to

remove the electrodes—merely to grip them in the holders in a lower position. Nor is it necessary to remove the electrode cooler. The attachments are released between the lever system, mentioned above, and the roof ring. The roof raise mechanism is then swung aside, carrying with it the electrode coolers but leaving the roof itself in position, on top of the body, where it can be replaced with a new one by the shop crane. The whole operation of roof changing can be carried out in half an hour.

The electrode masts are counterbalanced by a pneumatic arrangement incorporated within the masts. The total weight of each mast, together with the electrode assembly, is about 8 tons, and this is completely counterbalanced. By using air to counterbalance, the inertia of the moving parts is at a minimum. This system is so effective that only 3 h.p. motors are needed for raising and lowering the electrodes. The electrode regulator is of the well-known Rotodyne design, of which over fifty have been supplied since the war. To enable maximum metallurgical control to be carried out, the furnace is equipped with two doors, which are operated electrically.

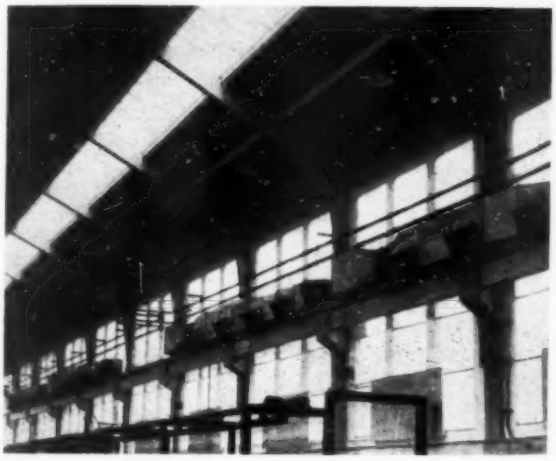
The transformer, made by The English Electric Co., Ltd., is of the external water-cooled type, working in conjunction with an air blast circuit breaker with a rupturing capacity of 750 MVA. The transformer is provided with a range of tappings to give alternative furnace operating voltages, the required tapping being selected by " on-load " tap change switchgear.

The ISCOR furnace is one of a number of large arc furnaces of this same general type, now being built by the Electric Furnace Co., Ltd., who are now associated with Lectromelt, Pittsburgh, and have exclusive rights to sell Lectromelt designs.

Heating and Ventilating a Mechanised Foundry

Sterling Metals' New Nuneaton Premises

A TOTAL of seventy independent plenum units have been incorporated in the heating and ventilating system of a new mechanised foundry at the Gipsy Lane, Nuneaton, premises of Sterling Metals, Ltd. Each of the units, which are all basically of the same design, comprises an air intake duct, a heater battery served from hot water mains, a Woods of Colchester 24 in. Aerofoil axial flow fan and outlet ducts. It was necessary to break up the system into such a relatively large number of divisions as the space available for heating and ventilating equipment was very restricted, being mainly confined to narrow areas immediately under the roof valleys. This installation is of particular interest at the present time, as the provisions of the Foundry Acts which recently came into force govern for the first time, among other things, the proper ventilation of foundries. In recent years, too, there has been considerable modernisation in British foundry practice, especially in mechanising the large scale production of small and medium size castings.

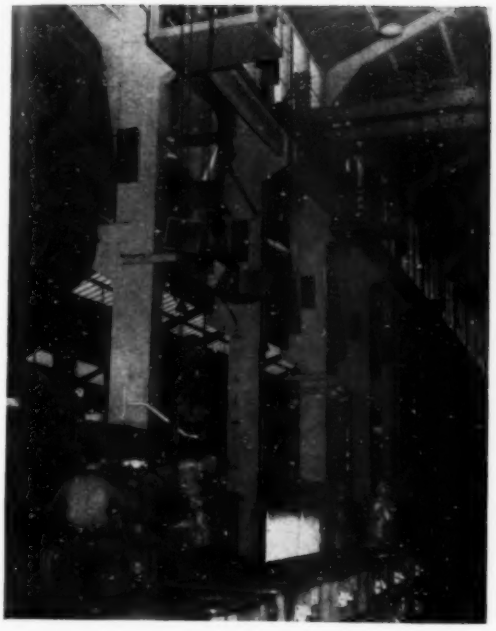


Plenum units as mounted on the side walls.

A complete plenum unit is situated between successive stanchions. Above the gantry rails is the air intake duct, heater battery and Aerofoil fan. The delivery duct is immediately below the rail, as is the Sunzway radiant heating panel.

Sterling's new foundry, one of the most modern in the world, is intended mainly for the production of small non-ferrous castings for the motor car and aero industries. Designed for semi-automatic operation initially, this plant is intended to become Britain's first fully automatic foundry. Whilst adjoining the company's existing premises at Nuneaton, the new building is more than an extension and has been planned as a self-contained production unit.

Dimensions of the building are : 500 ft. long, 400 ft. wide, and an average of 35 ft. high. It is of fabricated concrete construction, with a roof of corrugated aluminium sheeting. A combined plenum and radiant heat system gives overall heating and ventilation up to the highest industrial standards. These require a tempera-



The arrangement of the Deflector outlet grills can be seen on the delivery duct between the first and second stanchions.

ture from 55–60° F. for manual and semi-manual workers when the minimum outside temperature is 32° F.

In their design, the heating and ventilating engineers, Richard Crittall & Co., Ltd., had to take into consideration these three factors :—

(1) foundry production and processing involves considerable localised heat generation ;

(2) large quantities of fume and dust laden air are extracted in the course of processing by Sterling's production equipment ; and

(3) the system had to be concentrated immediately beneath the roof valleys to preserve the spaciousness of the building and the natural light from glass panels in the roof and extensive windows.

The plenum system adopted provides for an even distribution of heat to make up for the large extraction of warm air by the foundry equipment, and counteracts any marked ingress of cold draughts. Dividing the system into small units also gave the advantage of localised control.

Considerable ingenuity in design was required to keep the plenum units within the narrow spaces under the roof valleys, since the main carrying beams for travelling cranes were located at the same points. The Woods 24 in. Aerofoil fans in sixty of the units are each rated to move 8,000 cu. ft./min. of air against 0·5 in. water gauge. The remaining ten Aerofoils each give a duty of 5,000 cu. ft./min. against 0·75 in. water gauge. These straight-through air flow fans have high efficiency, compact design and are easily fitted in line with the duct, important space saving advantages in this installation where the heating and ventilating equipment was confined to narrow limits.

In addition to the fan and air heater battery, each plenum system comprises an air intake duct, which collects atmospheric air from above the roof valleys, and approximately 30 ft. of distributing duct extending between the main stanchions of the building. Most of the distributing ducts are fitted with five adjustable Crittall Deflector outlet grilles, the air velocity at the grilles being 950 ft./min. giving a throw of about 50 ft. The majority of the units are situated above the crane gantry rails, with the distributing ducts and grilles immediately underneath and about 12 ft. above floor level. In a few cases the air discharge is arranged from above the gantry rails.

Air extraction is effected mainly by extract equipment fitted to the foundry plant. In order to collect and exhaust any fumes which may escape into the foundry, thirty-six Woods Series A roof extract units have been installed. A further six of these units are also fitted in the roof of an adjacent building, where sand for the casting moulds is handled. The roof extract units have 18 in. diameter Woods propeller fans which are rated to move 3,540 cu. ft./min. With this size fan, the motor is mounted below the impeller within the base of the unit, so that servicing can be carried out from inside the building. The cowl has a four-way outlet of high aerodynamic efficiency, designed for minimum restriction of air flow whilst providing ample weather protection. Wind pressure, which may restrict the output of wall-mounted exhaust fans, will actually improve the performance of this unit.

The Use and Abuse of Science

An appeal by 43 scientists to their fellow scientists was recently issued in Great Britain. It asks them to consider their personal responsibilities for the application of their scientific knowledge and skill to warfare.

This four-page document is a brief, closely-reasoned analysis of the present situation ; it points out the heavy drain on scientific manpower and resources at present made for military research and development, which is handicapping industrial research in this country and impeding the development of backward areas. Many scientists and technologists are becoming uneasy through the perfection of nuclear weapons of mass destruction. Similar appeals made to their fellow scientists by groups in Germany and U.S.A. are quoted in two appendices.

This is a matter on which the individual must be left to draw his own conclusions and reach his own decisions, but it cannot be denied that the purpose of his training and activity is to-day a proper concern of the scientist.

Copies of the appeal may be obtained from the Clerk of the Quaker Scientists' Fellowship, Norman Clarke, 106, Olive Avenue, Leigh-on-Sea, Essex.

Powder Metallurgy Press Agency

George Cohen, Sons & Co., Ltd., are now sole agents in Great Britain for the well-known Dorst automatic press for powder metallurgical applications. The Dorst press is a modern high speed mechanical machine, silent in operation and widely used in the U.S.A. It will produce both simple components and components with complex changes of section, either with tools designed for the conventional cam operated press or with tools designed on Continental principles. The press is available in a range from 10 to 100 tons pressure.

Dud Dudley

An Overestimated Writer

By R. A. Mott, D.Sc., F.R.I.C., F.Inst.F.

In an article in the July 1956 issue, Mr. Eric Simons wrote in praise of the achievements of Dud Dudley, with special reference to the use of pit coal in iron making. The present author strongly refutes the suggestion that Dudley was anything but a mountebank, and argues that his claims were technically impossible.

ERIC N. SIMONS in his article in this Journal[1] claimed that "Dud Dudley was a remarkable inventive genius, and there is good reason to believe that he succeeded in making iron with pit coal, the fuel serving for both wrought and cast metal," and that this "ranks him as a great metallurgical genius." He says, further, that Dudley "undoubtedly focused men's minds on the potential value of pit coal so firmly that the eventual triumph of Abraham Darby was brought nearer, perhaps, than it otherwise would have been"; in this, "perhaps" strikes the only true note in a farrago of nonsense. Mr. Simons shows little of the critical faculty which a writer on historical matters should reveal, fails to show familiarity with the literature of his subject[2,3], and perpetuates fables which are now discredited.

Bar (or wrought) iron of high quality was not made from coke pig iron, using coal directly as the fuel, until Cort developed his puddling process in 1783–4. Pig iron was not made, using coal directly as the fuel, until Nielson had developed the hot blast in 1828, by which time blast furnaces were 40–50 ft. high, except in S. Wales where they were still higher. This height was an important factor in enabling lump coal to be used directly in the furnace, for some of the sulphur was removed from the coal in the upper levels of a furnace—at above 500° C. and before the reduction of the ores by carbon monoxide began—and escaped as hydrogen sulphide in the top gases without reacting with the iron. The remainder of the sulphur was removed in the hearth where the hot blast enabled the high melting point slags of high basicity ($CaO/SiO_2 = 1 \cdot 5$) to be used.

Before the hot blast was used blast-furnace slags were of lower basicity ($CaO/SiO_2 < 1 \cdot 0$) and were less capable of removing sulphur. Before the introduction of cylinder blowers operated by a Watt steam engine (1777), furnaces were low, the first at Carron (1760), for example, being only 29 ft. high, whilst that of Abraham Darby I (1709) was only 21 ft. high, a value which is not improbable in respect of Dud Dudley's day. In such a furnace Dud Dudley could not desulphurise his iron using large lump coal as a fuel. With charcoal as the fuel, reduction was "direct," i.e. with solid carbon in the bosh or hearth, and not with carbon monoxide as in the upper reaches of a 45-ft. furnace of 6,000 cu. ft. capacity used with a hot blast. In such a small furnace as Dudley could use, that part of the sulphur of the coal which is liberated at about 500° C. as hydrogen sulphide would pass into the reduced iron, and could not be removed from it by a slag of low basicity.

The Problem of Sulphur

Abraham Darby I resolved this problem by coking his lump coal, and so removed that part of the sulphur in coal which is released at low temperatures. Moreover, he was fortunate in having a coal, the Clod coal, which is of very low sulphur content (0·4%), so that he could remove the residual sulphur with a slag of low basicity. Despite this, it was not until 1734 that the output from each of his two furnaces exceeded 6 tons per week, for the lower reactivity of coke as compared with charcoal enforced a longer time of contact (a lower rate of drive) to carburise the iron, and so to yield the grey iron which would flow from the furnaces. In 1734, the output from each furnace was increased by the use of a horse-gin pump which returned the water from the pool tail of the water wheel (which operated the bellows) to be used again. Even before this step was taken, Coalbrookdale was much more favoured than was the Dudley area for water supply and, in fact, the widespread development of the coke blast furnace in the Black Country had to await the development of the steam engine, because the topography of the land was unsuitable for the operation of water-wheel-operated furnaces.[4] Moreover, despite the direct use of coal in a tall blast furnace with a hot blast and a very basic slag in S. Wales and Scotland *ca.* 1840, this practice did not develop in the Black Country until much later (*ca.* 1880), the delay being due to the fact that the coals in the other areas mentioned were more suitable for such a process.

In the days of the charcoal blast furnace, because of the low sulphur content of the charcoal and the ores, a basic slag was not necessary and the basicity ratio was usually 0·25, giving a thin slag of low melting point. So little was the significance of the basicity of the slag that in many areas, e.g. South Yorkshire, the charcoal iron industry did not use limestone in the burden,[5] and where it was used, e.g. in the Brecon area,[6] it was to ensure a more complete removal of iron from the slag rather than to achieve desulphurisation of the iron.

It is not legitimate to assume that Dudley used coke in his blast furnace (as some[7] have assumed, merely because of the eventually successful process of Abraham Darby I), for at the time when Dudley says Lord Dudley

1 Simons, E. N., *Metallurgia*, 1956, **54**, 21.
2 "Dud Dudley and the Early Coal-Iron Industry," Mott, R. A., *Trans. Newcomen Soc.*, 1934–5, **15**, 17.
3 "The Truth about Dud Dudley," Schubert, H. R., *J. Iron & Steel Inst.*, 1950, **166**, 184.
4 Gale, W. K. V., *Trans. Newcomen Soc.*, 1943–4, **24**, 14.
5 Baker, H. G., *Trans. Newcomen Soc.*, 1944–5, **24**, 113.
6 Percy, John, "Metallurgy—Iron and Steel" (London), 1864, p. 898.
7 e.g. Scrivener, H., "History of Iron Trade," 1841; Smiles, S., "Ironmakers and Toolmakers," 1863; Percy, J., *loc. cit.*

applied for a patent (March 10th, 1620, New Style), the patent (No. 15*) of Sir William St. John and others was being considered and was granted on April 25th, 1620; this was to " charke " pit coal and " to use and ymploye the said fewells soe charked in anie open or plaine furnace " for the casting and refining of iron. Moreover, Dudley was not content to claim that he could use the large lump coal which blast furnace operators of the late 19th century used in tall furnaces, but claimed that he could use small coal (" this my Invention will preserve many Millions of Tuns of Small-cole in Great Brittain . . . fit to have it made Pit-iron with "). The small coal of the Dudley area is non-coking and cannot, even with modern methods, be made into a coke;[8] it could not be used directly in the blast furnace with the feeble blowing power of bellows.

If Dudley had used large raw coal in a 20-ft. furnace of 600 cu. ft. capacity with a cold blast, even with limestone in the burden, his product would have been a " red short " iron which, because of its high sulphur content, would have broken under the hammer when hot. It is not impossible that he made castings with such an iron—the " iron of sorts " which Ashton is prepared to concede[9]—but that he could desulphurise such an iron in a refinery—as he claimed—is metallurgically impossible.

No-one succeeded in desulphurising red-short iron from a blast furnace until the soda-ash process—like that used for the basic Bessemer process at Corby—was developed *ca.* 1935 and, even with liquid iron at a much higher temperature than could be obtained in a cold-blast charcoal furnace, the amount of desulphurisation that can be effected is limited to 0·10% of sulphur—much less than the content of a red-short iron.

Dudley was not modest in his claims. He claimed that not only could he smelt iron ore with coal, but that he could refine the cast iron with coal to good merchantable bars suitable for the most onerous requirements, such as firearm making. Such processes in the 17th century were beyond the abilities of a metallurgical genius: they could only be achieved with a quill and considerable imagination. Thus Dudley's claims are so fantastic that they can be dismissed as figments of the imagination. His imaginative powers were considerable, for his alleged removal from his first furnace by " jealous ironmasters " was, in fact, by his father.[2] His veracity has been dealt with at length elsewhere[2, 3].

Tinplate Claims

In 1646 (like most Royalists) Dudley was classified by the Parliamentarians as a " delinquent." Like many child delinquents of modern times, he might be said to have had an unsatisfactory home background,† resulting in an inferiority complex which led him to make claims to draw attention to his own importance. His claims to be moved by patriotism are ill-founded. Andrew Yarranton[10]—a reliable commentator—has recorded that he (Yarranton) was sent by Thomas Foley and other ironmasters to see the method of tin plating in Saxony in 1660, and brought back workmen to start the process in England. Thomas Foley was the Treasurer of the Society of the Mines Royal and the Society for the Minerals and Battery (which were concerned with grants to work gold, silver, copper, tin, lead and other ores in England) and Dud Dudley was one of the assistants. The first trial tin plates were successful and arrangements had been made for large-scale development when this was stopped by a " trumpt up " patent. Yarranton records that " the making of tin plates was neither proceeded in by us, nor possibly could be by him that had the patent, because he that hath the patent, nor them that hath countenanced him, can make one plate fit for use." The patent[11] stated: " whereas we have been informed by . . . Wm. Chamberlaine and Dud Dudley Esquires that by thir industry and study with much charge and expenses they have attained to the perfection of plateing of steele, iron, brasse and copper and that of the tynning of the same plate being their own invention and never before done or used in these our Kingdomes "; it was granted for 14 years.

This " metallurgical genius " (whose achievements were not with coal but with graphite), this " unrequited patriot " (who retarded the development of the tinplating industry for 60 years), this exhibitionist (who was thrown out of his works by " jealous ironmasters "—his father, the patentee?) found favour with bibliographers and industrialists.[12] It is desirable that historians and metallurgists, at least, should recognise him for what he was. Two definitions from Lloyd's Encyclopaedic Dictionary (1895) seem suitable:—

(1) a mountebank—a boastful and false contender, a quack; or
(2) a charlatan—an assuming, empty pretender to knowledge or skill.

† He was the eldest of a family of 11 illegitimate children.

8 Mott, R. A., *Fuel*, 1934, **13**, 356.
9 Ashton, T. S., " Iron and Steel in the Industrial Revolution " (London), 1924, p. 12.
10 Yarranton, Andrew, " England's Improvement by Sea and Land" (London), 1677.

11 Patent Roll 13 Car. 2, recorded by E. W. Hulme, *Law Quarterly Rev.* 1902, p. 281.
12 e.g. John Bagnall of Golds Hill Ironworks, West Bromwich, who by reprinting it in 1854, unfortunately denied Dud Dudley's " Metallum Martis " (1665) the obscurity which it deserved; J. Mitchell who, in his Bessemer Memorial Lecture (*J. Iron & Steel Inst.*, 1956, **183**, 179), linked Bessemer with Dud Dudley, Huntsman, Cort and others.

Correspondence

MR. SIMONS' COMMENT

The Editor, METALLURGIA.
Sir,

Dr. Mott has a good case, weakened by the personalities in which he sees fit to indulge. He reminds me of the Baconians, who have innumerable ingenious arguments for proving that Shakespeare did not write his plays. If Mushet had never existed, and the documents regarding Bessemer were few, it would be possible for a future Dr. Mott to write of him (Bessemer) as a quack, a failure, because certainly the process he invented was not in itself capable of producing sound steel. Until spiegeleisen was added, the record is one of disappointment and doubt, while the ironmasters of Bessemer's day were as hostile to his ideas as Dr. Mott to Dudley. This does not in the least injure Bessemer's claim to be regarded as a genius.

I know little about coke, except that I once had to sew it into the corner of bayonet sacks; Dr. Mott knows little about human nature. He asks us to believe that a *known* quack and charlatan, who could only have thrived on the ignorance of his customers and clients, was such a fool as to publish late in life claims that had already been proved false; that everyone must have known were false; and that could have done him little, if any, good. But having written such a book, is it likely that he would,

in the circumstances of his time, say how he had done it (made iron) in detail ?

However, I say in my article . . . " he succeeded in making iron with pit coal . . . some doubt exists as to the genuineness of Dudley's technical success." And later I write " . . . Professor Ashton points out that he (Dudley) never mentioned that he at any time tried to coke the coal, and in view of the feeble blowing apparatus available at the time it is doubtful . . . whether sound iron could have been produced with the raw fuel." The opinion that Dudley *did* discover a process " whereby iron could be made from mineral fuel " was quoted not as my own, but as Professor Ashton's.

Dr. Mott considers that Dudley's statement that he was thrown out of his works is invalidated because the " jealous ironmaster " who did it was his own father. He evidently knows little either about jealousy or about fathers. The throwing out of sons might almost be regarded as a medieval hobby of fathers. I am all the more inclined to believe Dudley.

I am not in the least repentant for having written the story of Dud Dudley. I still consider that he had genius, which Dr. Mott almost, but not quite, concedes in his opening paragraph. I still believe, despite this ' bon Mott ' from Sheffield, that Dudley " had something," as Bessemer had, but unfortunately what he had we shall never know. Not even Dr. Mott *knows*, and for my part I am satisfied to be in the same boat with Mr. Mitchell and Professor Ashton.

Yours faithfully,

ERIC N. SIMONS.

Westham, Pevensey.
November 12th, 1957.

New and Revised Standards

METHODS FOR THE ANALYSIS OF ALUMINIUM AND ALUMINIUM ALLOYS. (B.S. 1728 : 1957.)
Part 8 : IRON (ABSORPTIOMETRIC 1 : 10-PHENANTHROLINE METHOD). PRICE 3s.
PART 9 : MANGANESE (VOLUMETRIC ARSENITE/NITRATE METHOD). PRICE 3s.
PART 10 : MANGANESE (ABSORPTIOMETRIC METHOD). PRICE 3s.

THESE new publications form part of a series of methods for the analysis of aluminium and aluminium alloys. Elements dealt with in other parts of the series were : copper, magnesium, zinc, iron and manganese. Part 8 specifies an absorptiometric method for determining iron in alloys containing smaller amounts of iron, and is an alternative method to the volumetric method in Part 6. Parts 9 and 10 relate to the determination of manganese. The volumetric method is intended for use with alloys containing higher percentages of manganese than those which would normally be determined by the absorptiometric method in Part 10. The standard specifies the reagents to be used and certain recommended methods of sampling and test procedure. An indication is given of the expected reproducibility, derived from experiments carried out by a number of independent analysts.

SCHEDULE OF COPPER AND COPPER ALLOYS TUBES (B.S. 2871 : 1957). PRICE 15s.

THIS schedule is the first of a series to be prepared for copper and copper alloys in various wrought forms. The 88-page publication contains all the requirements from existing standards for copper and copper alloy tubes, with adequate cross reference to the individual standards, which will for the present continue to exist. The new standard also contains requirements for six alloys not previously included in standards for tubes.

The general requirements applicable to all materials are grouped in Section I, together with the relevant tolerances, and the specific requirements for each of seventeen materials are dealt with in Section II. The latter include the chemical composition (with cross references to the existing standards in which the chemical compositions appear), the conditions in which the material is available, and the mechanical properties. Materials are identified by symbols, which in future schedules for wrought products will be used for the same alloys wherever they appear. The same symbols will be introduced into the existing British Standards as and when they are revised. (They have already been included in the recently issued revision of B.S. 1464 : 'Solid Drawn Copper Alloy Tubes for Heat Exchange Equipment in the Petroleum Industry').

The requirements included in Sections I and II apply to the materials when they are required for general purposes. But many of the existing indivdual standards include requirements which are specific to an end-use which may differ from, or be additional to, those for general purposes, hence, Section III of the standard, where requirements for particular applications are dealt with.

The standard contains a " fold-out " summary which shows the chemical compositions of all the copper and copper alloys which are to be included in any one of the schedules for the wrought products. When including in the one document all the requirements from all existing British Standards for tubes, certain anomalies became apparent, and where possible they have been eliminated. Corresponding amendments to the existing individual standards will be made by means of amendment slips.

NICKEL-IRON TRANSFORMER AND CHOKE LAMINATIONS (B.S.2857 : 1957). PRICE 3s.

THE laminations specified in this new British Standard are of three standard thicknesses : 0·015 in., 0·008 in., and 0·004 in. There are four classes of material from which they may be made, and for each of the classes and thicknesses, minimum guaranteed permeability figures at 50 c/s. are specified, these figures varying with the mean magnetic path. The standard contains two illustrated appendices. The first gives a method of test for space factor, and the second a method for determining—at 50 c/s.—the permeability of laminations.

Among the organisations concerned in the preparation of B.S.2857 were the British Electrical and Allied Manufacturers' Association, the Electrical Sheet Conference, the Radio and Electronic Component Manufacturers' Federation and the Telecommunication Engineering and Manufacturing Association.

Copies of these standards may be obtained from the British Standards Institution, 2, Park Street, London, W.1.

NEWS AND ANNOUNCEMENTS

Institution of Metallurgists Registrar-Secretary

THE Council of the Institution of Metallurgists announces that Dr. A. D. Merriman, G.C., who has been Registrar-Secretary for the past ten years will retire on December 31st, 1957. During Dr. Merriman's tenure of office the Institution has grown from a membership of less than 1,600 to more than 3,500 and in a recent appreciation of his services by Professor F. C. Thompson, a Past-President, tribute was paid to his part in firmly establishing the Institution as the professional organisation of metallurgists.

Dr. Merriman will be succeeded on January 1st next by Mr. R. G. S. Ludlam, who has been Assistant Registrar in the University of Leeds since 1951. He is aged 36 and was educated at Schools in South Africa and Southern Rhodesia, followed by King Edward VII School at Sheffield. He graduated in the University of Sheffield with First Class Honours in English Language and Literature in 1948 and was awarded also the University English Prize and the Gibbons Prize in that year. During the war he served in the Royal Air Force and before joining the staff of the University of Leeds he spent two years in the Department of the Clerk to the London County Council.

Powder Metallurgy Meeting

THE Inaugural Meeting of the recently-formed Powder Metallurgy Joint Group of The Iron and Steel Institute and The Institute of Metals, will be held on Wednesday, December 4th, at Church House, Great Smith Street, London, S.W.1, at 10.30 a.m. After a lecture by the Chairman of the Group, Dr. Ivor Jenkins, on "Recent Developments in Powder Metallurgy," there will be a Discussion on "Developments in the Production and Quality of Metal Powders," based on a series of short introductory papers. Visitors will be welcome; tickets are not required.

Membership of the Joint Group is restricted to membership of the Institutes. Particulars may be obtained on application to the Secretary to the Group, Lt.-Col. S. C. Guillan, 17, Belgrave Square, London, S.W.1.

Fuel Efficiency in the Metal Industries

THE Metallurgical Engineering Committee of The Institute of Metals is arranging an all-day Informal Discussion on "Fuel Efficiency in the Melting and Thermal Treatment of Metals," to be held at the College of Technology, Gosta Green, Birmingham, on Wednesday, February 26th, 1958. Visitors will be welcome and tickets will not be required.

Conference on Precipitation Processes in Steels

A CONFERENCE on Precipitation Processes in Steels, arranged by the Department of Metallurgy, University of Sheffield, will be held in the Department, St. George's Square, Sheffield, 1, from July 2nd to July 4th, 1958. There will be four main sessions, dealing, respectively, with: (1) precipitation in ferritic steels; (2) precipitation in austenitic steels; (3) intergranular fracture in steels; and (4) precipitation during creep. Accommodation for participants in the Conference has been arranged in Stephenson Hall, University of Sheffield.

Attendance at the meetings will be limited and early applications are advised. There will be a Registration Fee of £2, which will cover the cost of pre-prints of a number of the papers to be presented, and of light refreshments during the sessions. Application forms and further information can be obtained from The Professor of Metallurgy, University of Sheffield, St. George's Square, Sheffield, 1.

Stockpile Beryllium Copper Disposal

THE Board of Trade announce that, in accordance with the policy set out in the 1956 Defence White Paper (Cmd. 9691, paragraph 125) of running down strategic holdings of industrial raw materials, they intend to dispose of 37 tons of beryllium-copper master alloy with a beryllium content of about 4%. This material is being offered for sale by open tender for delivery in December and January.

Forms of tender are obtainable from the Board of Trade, G.7, Lacon House, Theobalds Road, London, W.C.1.

Lecture Courses on Fatigue

A COURSE of ten lectures on "Engineering and Metallurgical Aspects of Fatigue" will be held at the Battersea College of Technology on successive Tuesday evenings, from 7 to 9 p.m., commencing on January 14th, 1958. The subjects and lecturers are as follows: "The Nature of Fatigue," Dr. A. P. Miodownik; "The Influence of Combined Stresses," S. R. House; "The Influence of Corrosion," Dr. P. T. Gilbert; "The Influence of Temperature," Dr. P. G. Forrest; "The Influence of Design" (lecturer to be announced); "The Metallography of Fatigue," P. J. E. Forsythe; "The Mechanism of Fatigue," Dr. T. Broom; "Fatigue Testing," M. G. Bader; "The Interpretation of Fatigue Data," H. L. Cox; and "The Fatigue Properties of Engineering Materials," R. J. Love.

The fee for the course is £1. Enrolment forms may be obtained from the Secretary (Fatigue Lectures), Battersea College of Technology, Battersea Park Road, London, S.W.11.

Education in Polarography

THE Polarographic Society is organising a one-day Meeting on "Education in Polarography" to be held at the Birmingham College of Technology on Thursday, March 20th, 1958. Various aspects of the topic will be discussed, and the programme will include a film on polarography, which has been prepared by the Czechoslovak Polarographic Research Institute under the direction of Prof. J. Heyrovsky (President of the Society). Dr. Masek will be coming from Prague to give a commentary on the first British showing of the film.

Non-members of the Polarographic Society who wish

to receive further details when these are circulated should send their names and addresses to: Mr. D. R. Curry, 28, St. Mary's Way, Baldock, Herts. Any organisation or institution which is interested in the possibility of showing the two-hour film in other centres during Dr. Masek's visit is asked to contact the same address as soon as possible.

Clustering and Precipitation in Metals

A LECTURE on "The Mechanism of Clustering and Precipitation in Metals" will be given on Wednesday, January 15th, 1958, by Dr. David Turnbull, Manager of the Chemical Metallurgy Section of the Research Laboratory of The General Electric Company, Schenectady, N.Y. The lecture, which is being arranged by the Metal Physics Committee of the Institute of Metals, will take place at the Institute's Headquarters, 17, Belgrave Square, London, S.W.1, at 6.30 p.m. The meeting is open to visitors, without tickets.

Stockpile Zinc Disposal

IN accordance with the programme of disposals announced on August 2nd, the Board of Trade are to offer about 9,000 tons of zinc for delivery and pricing over the three months December, 1957, to February, 1958, inclusive. About 3,200 tons will be offered for sale by open competitive tender, and the remainder will be offered to the original suppliers or their agents.

Import Duties Exemption

THE Treasury have made the Import Duties (Exemptions) (No. 14) Order, 1957, which exempts certain spent platinum catalysts from duty under the Import Duties Act, 1932. The Order came into operation on November 4th, 1957, and has been published as Statutory Instruments 1957, No. 1848.

Personal News

STEEL, PEECH AND TOZER, a branch of The United Steel Cos., Ltd., announce that Mr. J. TAYLOR has been appointed Sales Manager, Hot Strip Rolling Mills, MR. I. MULHEARN, Sales Manager, Cold Strip Rolling Mills, and MR. P. SHERWELL, Manager, Central Sales Office.

MR. C. B. WRIGHT has been appointed Technical Sales Manager of Davy and United Roll Foundry, Ltd., consequent upon the resignation of MR. L. W. H. ASTON to take up a new post elsewhere.

MR. M. SEAMAN, having recently become Director and General Manager of British Oxygen Gases, Ltd. (Equipment Division), has relinquished his appointment as Director and General Manager of British Oxygen Engineering, Ltd. MR. R. J. FOSTER, formerly General Manager, has now been appointed Director and General Manager of British Oxygen Arc Equipment, Ltd.

MR. R. OLIVER has recently resigned his position with P.E.R.A., to take up an appointment as Chief of the Metals Development Department at the General Electric Co., Ltd., Wembley.

MR. L. HIGHTON, J.P., Managing Director of Workington Iron and Steel Company, a branch of The United Steel Cos., Ltd., will relinquish this position on December 31st on completion of 47 years' service. Mr. Highton will continue to be a director of United Steel and of its associated companies in Cumberland. MR. T. S. KILPATRICK, Director and Deputy General Manager at Workington, will be appointed Director and General Manager on January 1st next. MR. D. R. WATTLEWORTH O.B.E., retires as Director and General Works Manager on December 31st, after 50 years' service. He will be succeeded as General Works Manager by MR. T. SANDERSON, who is at present Assistant General Works Manager.

ALUMINIUM UNION, LTD., announce that MR. G. T. FIELD, formerly of the Board of Trade, has been appointed to an executive position at their London Office.

MR. H. P. HUGHES, formerly Works Manager and Technical Adviser to Union Carbide, Ltd., Alloys Division, has now taken up the position of Works Manager with Gemec, Ltd., whose new £4,000,000 polyethylene plant at Grangemouth, Scotland, is nearing completion.

MR. A. J. SPEAKMAN, Deputy Director of the British Productivity Council, has been appointed Work Study Manager in the Operational Research and Cybernetics Department of The United Steel Cos., Ltd.

MR. G. M. HARVEY has been appointed Managing Director of British Oxygen Wimpey, Ltd. He relinquishes his appointment on the Company's Board as Design Manager.

Obituary

WE regret to record the death of DR. PAUL D. MERICA in New York on Sunday, October 20th. Born in Warsaw, Indiana in 1889, Dr. Merica received his A.B. degree from the University of Wisconsin in 1908 and his Ph.D. in Berlin in 1914. From 1914 to 1919 he was associated with the Metallurgical Division of the U.S. Bureau of Standards, in Washington, and subsequently joined the International Nickel Co. of Canada, Ltd., becoming Director of Research and subsequently Assistant Manager of the Development and Research Department. He became Assistant to the President in 1932, a Director in 1934, Vice-President in 1936, Executive Vice-President in February, 1949, and President in May, 1952, retiring from the last position in April, 1954. Dr. Merica continued to serve the company on important projects and as consultant to the officers. He also continued as a Director of The International Nickel Co. of Canada, Ltd., and its United States subsidiary, The International Nickel Co., Inc.

In addition to his direction of executive and commercial affairs of the company, Dr. Merica had long been identified with its research activities in Canada, the United Kingdom and the United States, and had evolved numerous iron-nickel and copper-nickel alloys. For his contributions in the field of metallurgy and outstanding leadership in physical metallurgy, he was awarded the James Douglas Medal, in 1929; the John Fritz Medal, in 1938; the Institute of Metals Medal, in 1941; the Franklin Institute Medal, in 1942; and American Society for Metals Gold Medal, in 1951. Dr. Merica was an honorary member of the American Institute of Mining and Metallurgical Engineers, of which he was a former Vice-President and Director, as well as of the American Society for Metals.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Ultrasonic Engraving Tool

THE Mullard ultrasonic engraving tool type L.274, development models of which were shown at this year's Instruments, Electronics and Automation Exhibition, has now been put into full production. The L.274 is equally suitable for engraving surfaces or for drilling small holes of any shape in hard and brittle materials like glass, ceramics, tungsten carbide, and precious, semi-precious and synthetic stones and so on. For machining operations it may be used either as a hand tool or mounted on the Mullard precision drill stand type E.7682, and for engraving purposes it can be mounted in a standard pantograph machine.

For the majority of operations, the cutting tool is a soft steel tip, identical in shape and size with the hole or pattern it is required to make. A diamond-tipped or diamond-loaded tool is used for fine engraving. The cutting tool screws into the end of the velocity transformer, and can therefore be changed readily. The cut is variable from 0·005 to 0·25 in. maximum lateral dimension, and has a maximum depth of $\frac{3}{8}$ in.

The L.274 incorporates a water-cooled magnetostriction transducer operating at a frequency of approximately 27 kc./s. Transducer vibration is transmitted to the cutting tool by means of a resonant step-up velocity transformer. Power for the tool is supplied by the Mullard ultrasonic generator type L.275. This has an output of 30 W. and incorporates a feed-back system to maintain the output at the correct operating frequency without the need for manual tuning.

*Mullard, Ltd., Mullard House, Torrington Place, London, W.C.*1.

Flame Hardening Machine

A NEW oxy-acetylene flame hardening machine which provides surface hardening on sprocket teeth to prevent excessive wear, has been developed by Precision Heating, Ltd. The machine, designed with the co-operation of British Oxygen Gases, Ltd., is capable of hardening single, duplex and triplex sprockets of up to about 6 in. diameter. A full set of burners with suitable jet sizes is provided.

The sprocket wheel is located on a free-running arbor, and a pneumatically-operated indexing mechanism ensures that the sprocket can be indexed rapidly, one tooth pitch at a time, in an anti-clockwise direction. An oxy-acetylene blowpipe fitted with a burner is pivotted so that the burner can be placed over the top of the sprocket teeth: both blowpipe and the burner are water-cooled. The burners are interchangeable, and each is provided with a quench jet on either side, connected by flexible tubing to quick-release connectors. Oxygen and acetylene cylinders are connected through separate reducing valves to two flowmeters, a pneumatically-operated duplex gas valve, and then to the blowpipe. The flowmeters enable the gas flows to be adjusted for each type of burner, ensuring consistent hardening results.

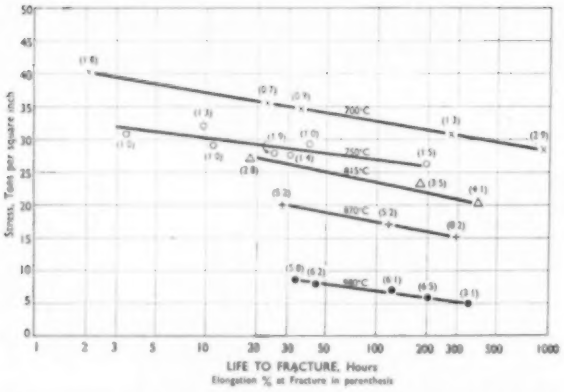
The indexing mechanism and burner are adjusted in relation to the teeth which require hardening, and a push button operates the gas valve, causing the gases to flow through the burner and be ignited by a small towns gas pilot jet attached to the rear of the burner. When correct flame conditions have been achieved, the burner is lowered on to the top of the sprocket teeth. The quench jets then start automatically and a timing mechanism also operates. At the end of the time cycle, the indexing mechanism advances the sprocket one tooth pitch in an anti-clockwise direction, bringing the heated tooth into the soluble oil quench. The root of each tooth is hardened to just above the p.c.d. (pitch circle diameter), and the tips remain soft. The teeth are heated to a temperature in the region of 820° C. When all the teeth have been hardened, a magnetically-operated counter returns to zero and the gas supplies are shut off. The blowpipe is swung clear, the indexing mechanism retracted, and the sprocket wheel replaced by another so that the hardening cycle can be repeated.

Full adjustment is provided for the blowpipe assembly, indexing mechanism and sprocket spindle. All movements have limit switches and are interlocked to prevent the commencement of the cycle until the blowpipe and indexing mechanism are in position. A built-in recirculating quench system is incorporated, and needle valves are fitted for fine adjustment of the quench jets. Manual control is also provided to enable the indexing mechanism and burner control to be adjusted independently for the purpose of setting-up.

Precision Heating, Ltd., Canbury Park Road, Kingston-on-Thames.

High-Temperature Casting Alloys

THE name Nimocast has been introduced by Henry Wiggin & Co., Ltd., to cover a range of high temperature nickel-chromium-base alloys for use in the cast form. Six alloys are now available in the series, five of which were developed in the laboratories of The Mond Nickel Co., Ltd. The Nimocast Alloys are complementary to



Stress/rupture data for Nimocast 258 obtained with test pieces machined from investment cast bars.

the well-known Nimonic Series of wrought heat-resisting alloys; some of them were previously included in the Nimonic Series, and others were known by laboratory designations. In the following notes, the earlier names are given in brackets.

Nimocast 75 (formerly Nimonic C.75).—This alloy may be used under conditions involving low stresses, but requiring good resistance to oxidation. Nimocast 75 does not respond significantly to heat-treatment and is normally used in the " as-cast " condition, or after a stress-relieving treatment.

Nimocast 80 (formerly Nimonic CC).—Nimocast 80, corresponding to Nimonic 80, has considerably higher room-temperature mechanical properties and creep-resistance than Nimocast 75. It is used for gas-turbine stator blades and pre-combustion chambers of high-performance diesel engines. Nimocast 80 is normally used in the fully heat-treated condition.

Nimocast 90 (formerly Nimonic CB).—This alloy, the casting version of Nimonic 90, also responds to heat-treatment and is generally used in the age-hardened condition. In general, Nimocast 90 is to be preferred to Nimocast 80 for high-stress, high-temperature applications in view of its better castability and superior strength. At 750° C., Nimocast 90 shows stress-carrying capacity inferior to that of the corresponding wrought alloy, but at 870° C. and above, Nimocast 90 carries at least as high a stress for a given life as Nimonic 90.

Nimocast 242 (formerly C.242).—This alloy was developed by Rolls Royce, Ltd., for investment casting applications involving high resistance to thermal shock. It is used in the " as-cast " condition at temperatures up to 1,050° C. for such components as stator blades for gas-turbine engines.

Nimocast 257 (formerly MC.57).—This alloy has properties intermediate between those of Nimocast 75 and Nimocast 90, giving adequate proof stress combined with good ductility at temperatures in the range 600–700° C. It is of particular interest for centrifugally cast rings used in gas turbines. The alloy is used in the fully heat-treated condition.

Nimocast 258 (formerly MC.58).—This is a recently developed alloy which has good stress/rupture properties at temperatures higher than 950° C. It is similar in composition to Nimonic 100, the most creep-resistant alloy of the Nimonic Series. This alloy has the highest stress/rupture properties in the as-cast condition.

The above series of high temperature casting alloys, which are available for re-melting in the form of cast stick or foundry pig, offers a very wide range of properties for many engineering applications which require high resistance to oxidation and thermal shock, together with high tensile and stress-rupture properties.

Henry Wiggin & Co., Ltd., Wiggin Street, Birmingham, 16.

18kW H. F. Induction Heater

A NEW 18kW. high frequency induction heater by G.E.C. occupies less than 11 sq. ft. of floor space, yet provides sufficient power for surface hardening applications and for brazing heavy sections. It has a power output control which adjusts the impedance matching of the load by varying the coupling between the tank coil and the concentrator to which the heating coils are attached. Other controls are a mains switch, a remote control unit with stop and start push buttons, and an automatic re-setting process timer and switch.

A single work station is normally provided, but provision can be made for two. The work coils are easy to make and to interchange, being readily detachable from the generator and having water connections incorporated in them. Cooling is provided by a filtered air blast to the oscillator valve and interior of the set. A small amount of ordinary mains water is required for cooling the output transformer and heating coil. A water-flow switch renders the set inoperative unless sufficient water is flowing.

Power input is approximately 36 kW. at full load, with power output at 18 kW. The valves used are a BR.1102 oscillator valve and six G.E.C. GU.21 mercury vapour rectifier valves for full wave rectification of supply to the oscillator valve. Frequency of the unit is approximately 500 kc./s. An anode current meter indicates the output power, and an hour meter records

valve life. A green signal light indicates " mains on," and a red light glows when the set is in full operation. Interlocks are provided on all panels and doors to prevent the H.F. contactor being electrically closed inadvertently. H.F. filters are fitted in the supply leads to prevent unwanted H.F. currents being fed back into the mains supply.

The front panels of the unit are finished stove-enamelled polychromatic silver. The supports for a work table, which are fitted on the lower front panel and the output control guide plate are chromium plated. The remainder of the unit is stove-enamelled Oxford blue. To facilitate movement of the unit, retracting trunnions are provided at the base.

The General Electric Co., Ltd., Magnet House, Kingsway, W.C.2.

New Dexion Jigging System

A NEW type of jigging system which eliminates up to one-third of the construction time normally incurred in building slotted angle installations has just been introduced by Dexion, Ltd. Designated Speedframe, the new method can be applied to a wide range of slotted angle assemblies, and provides an adaptable method of mass-prefabricating identical frameworks.

Master frames or templates are made from slotted angle, and the jigging medium is represented by a simple metal stud, some three inches in length and recessed at the head to house a nut or bolt. Jigging is carried out in five simple stages. Firstly, the master frame is assembled accurately with its fixing nuts facing upwards, and Dexion jigging studs are screwed on to the bolt threads protruding above each nut. Bolts for the first copy frame are then dropped, head down, into the recesses at the top of each stud and the pre-cut lengths of slotted angle, for the new frame, are then placed in position. Nuts are positioned and tightened up and the complete frame is then lifted off.

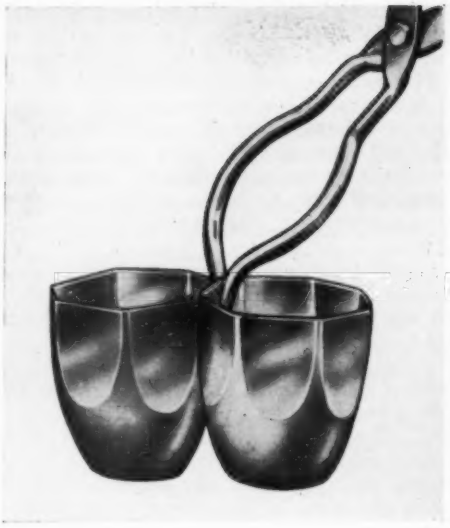
The advantages of this system are considerable. Copy frames can be assembled in a matter of minutes and skilled labour is unnecessary. Results are accurate and mistakes in bolt-fixings eliminated. No measuring is necessary once the master frame has been built and, on a lengthy repetitive job, new operatives can take over with few instructions and very little supervision.

The studs are cylindrical in shape and made from cadmium-plated steel. The recess is 12-sided and marries with the Dexion $\frac{5}{16}$ in. B.S.W. nut or bolt in general use, while the obverse end features a tapped hole of similar size.

Dexion, Ltd., Maygrove Road, London, N.W.6.

Polygonal Platinum Crucibles

THOROUGHLY tested under actual laboratory conditions, the new polygon-shaped platinum crucible recently introduced by Baker Platinum has demonstrated considerably greater stability, versatility and ease of handling than the conventional, standard round-shaped type. As a result of its flat sides and more stable flat bottom, it offers several advantages. Firstly, due to the crucible's flat sides, a better surface is provided for tongs, thus avoiding the tendency to crimp to which conventional crucibles are prone. Another advantage is that, due to their shape, there is always a corner " spout " opposite



each flat side, which facilitates easy pouring, and with these flat sides, two crucibles can be picked up and handled at one time. Baker polygon-shaped platinum crucibles are now available in the same capacities as the K series and the price is no more than for the old conventional round-shaped crucibles.

Baker Platinum Division, 52 High Holborn, London, W.C.1.

Metal Rectifiers for Welding

WHILE alternating current is satisfactory for most arc welding, there are certain cases where it is either easier or more effective to use direct current : in a number of applications it is, of course, essential. Examples include the welding of aluminium, copper, nickel and their alloys, corrosion resisting steels, and mild steel in the lighter gauges. Traditionally, D.C. for welding is supplied by a motor generator, and these have proved reliable enough, but the advantages of the metal rectifier are such that it is rapidly replacing the motor generator in a wide range of industries. Pioneered in this country by Quasi-Arc, Ltd., the metal rectifier is already giving a more efficient welding service in many fields.

Typical of the new range of Quasi-Arc rectifiers is the MOR.375 single operator welding set. It consists essentially of a step-down transformer, a variable reactor and a selenium metal rectifier, all enclosed in a strong sheet metal cabinet measuring (with wheels) 32 × 33 × 51 in.—thus taking up the minimum of floor space—and weighing just over 8½ cwt. The transformer is designed for 3-phase operation, and the secondary of the double wound unit is completely isolated from the mains supply, ensuring safety. Current regulation is by means of a 3-phase moving core reactor, giving stepless control of output over the full current range from 30 to 375 amp. and adjustments of current output can be made on load. The position of the core is adjusted by a control handle in the top cover of the housing which is linked to a rotating calibrated drum to show the setting. The rectifier is of the selenium plate type, 3-phase, bridge-connected to give full-wave rectification. The components are cooled by a fan

fitted with a centrifugal switch preventing the equipment being used if the fan fails.

In another model, the MR.375, current control is effected by means of a saturable reactor which enables a light-weight remote control device to be incorporated. This current selector gives the welder complete control over the full current range, and adjustments can be made with the set on load. Thus the welding plant can be located well away from the workpiece, and yet the welder can adjust his welding current without moving to and fro.

The main advantages of the metal rectifier stem from the absence of any continuously moving parts, except the cooling fan. This means that maintenance is reduced to a minimum ; the machine is silent in operation. Assuming an operating factor of 33⅓% (that is, the welding load is taken for one-third of the time the machine is in use), then a power saving of over 40% is claimed. The minimum current is lower than that normally available on rotary plant, so that the smallest and largest electrodes may be used with equal facility. Still more important is the welding performance. In all welding operations there is a tendency for drops of molten metal to cause momentary short-circuits, so that the demands on the machine supplying the current are constantly changing. Performance largely depends on the speed of the machine's responsiveness to these changing demands. The rectifier gives superior arc stability, a smoother weld and greater ease of striking. In fact, the metal rectifier enables relatively unskilled labour to carry out welding operations which, with earlier equipment, would call for a high degree of skill.

Other models of varying capacity up to 1,200 amp. are produced for automatic and semi-automatic welding. The MRS.425, for example, is designed for the Sigma (shielded-inert-gas-metal-arc) process in which a bare electrode is fed into a weld pool protected from atmospheric contamination by a shield of inert gas such as argon. Special rectifiers in the larger range are also designed for arc cutting.

Quasi-Arc, Ltd., Bilston, Staffs.

Fuel Improver for Residual Fuel Oils

A FUEL improver for residual fuel oils which has been developed and proved in France over a number of years is now available in England and throughout the Commonwealth. It is being manufactured by The Amber Chemical Co., Ltd., and marketed under the name Amber Desulfurol (SSR.509). It is claimed that the addition of this product to residual fuel oils will reduce the formation of sulphur trioxide by 50% to 75%, increase average carbon dioxide readings by 3% to 4%, and bring about an appreciable reduction in fuel consumption. These claims are based on experience in almost every industry over several years in France, and on trials recently carried out in England, reports of which are available from the manufacturers. In these trials no adjustments of the burners were made such as would tend to falsify the readings obtained.

In addition to the financial economies indicated by the test results, an important practical effect of the use of Amber Desulfurol (SSR.509) is the reduction not only of sulphur trioxide, but also of soot and smoke. This is of particular value to industries where atmospheric pollution can seriously hamper quality of production.

In the forge department of a large factory manufacturing cars in Northern France trouble was experienced from sludge, from sulphurous gases which forced the workmen to wear gas masks, and from sulphur scale on the billets. The use of the product dispersed the sludge, eliminated the sulphurous gases and prevented the formation of sulphur scale. In addition, the chief engineer found he could change to a heavier fuel oil at a lower pre-heat temperature, and at the same time reduce major maintenance stoppages by 75%. Other industries for which Amber Desulfurol (SSR.509) has proved of substantial assistance include non-ferrous foundries where sulphurous gases can be a major problem.

The Amber Chemical Co., Ltd., 11A *Albemarle Street, London, W.1.*

Spray Nozzles

ALFRED BULLOWS & SONS, LTD., announce the introduction of two additional air nozzles for use with their Bullows-Binks Model 19 spray gun. A high speed light-weight spray gun, the Model 19 is standard equipment in the U.S.A. to almost every major mass production manufacturer of motor cars, refrigerators and similar products. These two new nozzles, which are intended to supplement the existing range, are the 63PB and 67SA.

For use on pressure feed, the 63PB, a Bullows Group 1 air nozzle, will operate with any of five material nozzles varying from 0·040 in. bore to 0·070 in. bore. It is suitable for spraying the normal range of finishing materials, from thin spirit or water stains to primers and heavy enamels. It is complementary to the 66PE nozzle, giving better results on certain materials. A Bullows Group 2 air nozzle, the 67SA operates with the 67 material nozzle of 0·086 in. bore. It is designed for use with a syphon cup, and is suitable for use with aeroplane dope, heavy primers, fillers and cement paint. There has previously been no suitable suction type nozzle available for these Group 2 materials.

Both nozzles are hard brass stampings with taper location on material nozzles to ensure permanent concentricity. All critical machining is done after plating.

Alfred Bullows & Sons, Ltd., Long Street, Walsall, Staffs.

CURRENT LITERATURE

Book Notices

GENERAL GALVANIZING : A MANUAL OF GOOD PRACTICE

56 pp., numerous illustrations, diagrams and tables. Published by the Hot Dip Galvanizers Association, 34, Berkeley Square, London, W.1. 25s.

ALTHOUGH modern developments in the field of corrosion prevention are to be welcomed, traditional methods of combating the enormous wastage due to rust are by no means fully exploited. Since its formation in 1949, the Hot Dip Galvanizers Association has published a large volume of literature, not only to explain the function and uses of hot dip galvanized coatings, but also to encourage technical development in the industry. The Technical Committee of the Association in collaboration with the British Non-Ferrous Metals Research Association has now published this Manual as the first of a series of books to be issued as part of the Association's productivity service. The others, " General Galvanizing : A Manual of Costing " and " General Galvanizing : A Manual of Good Housekeeping and Safety " will be published shortly. The present volume is designed to give guidance on the practical aspects of the galvanizing process, and should prove particularly useful to managers and supervisors in the general galvanizing industry.

An introductory chapter outlines the process, distinguishes between the wet and dry methods, and also describes the structure of the coating and the effect of different basis materials. Operations such as pickling and fluxing which are necessary prior to dipping the work in the molten zinc are fully described, and special attention is paid to the preparation of castings for galvanizing. Full consideration is given to the control of preflux solutions in the dry process, and the relative costs and merits of ammonium chloride and zinc ammonium chloride as fluxes in wet galvanizing are compared. The section dealing with the actual dipping of the work examines the factors which affect the thickness and uniformity of the coating, and concludes with a brief description of the centrifuging of small articles such as bolts to remove excess zinc from the threads.

Further chapters deal with recommendations on the control of ash and dross formation during galvanizing, and methods of recovery of zinc from these unwanted by-products are also discussed. Handling and treatment after galvanizing are described, and an account of inspection and testing includes reference to possible defects in the coating, stresses the importance of coating thickness, and discusses the methods of measuring it. The prevention of white rust, which sometimes occurs on newly galvanized articles, is discussed in the chapter on transport and storage, and the final chapter of the book is concerned with finishing treatments, and emphasises the value of calcium plumbate paints as directly applicable to newly galvanized steel.

The book is fully indexed and provided with marginal headings for ease of reference. It is produced in a tough though attractive binding which will enable it to withstand rough handling and make it suitable for constant use on the shop-floor.

ALUMINIUM IN PACKAGING

Applications Brochure No. 11, The Aluminium Development Association, 33, Grosvenor Square, London, W.1. 10s. 6d.

THIS latest addition to the Aluminium Development Association's series of Applications Brochures represents the first British publication of its kind on a subject that has become of increasing importance in conjunction with modern concern both for the preservation of packaged goods and for attraction in display. It should be noted that the brochure deals only with expendable aluminium containers, packages and similar products made from thin gauge materials.

The brochure, which is illustrated in full colour, is addressed principally to designers and industrial users of packages, and it is strongly influenced in its text and method of presentation by the essentia llink betwen the ideas of the designer and the needs of the user. Thus, the package manufacturer may expect to find much of interest for him, but only such details of production methods as are needed by way of essential explanation.

Following a brief account of the place that aluminium has acquired in the packaging field—largely because of its assured supply and consistency of properties—the types of containers and packages are described : these include built up containers, deep drawn and impact extruded containers, foil wraps and packs, and seals, capsules and labels.

The above, principal, section of the book is followed by an outline of the composition and properties of aluminium packaging materials, in which brief notes are made concerning its non-toxicity, ease of forming, resistance to corrosion, strength, and light weight. Some account is given of the forms in which aluminium is available for this purpose : namely, foil, foil coatings and laminates, sheet and strip, and slugs for impact extrusions. There is a brief note on the process of printing down on aluminium. An Appendix summarises this information in tables of data which include the coverage areas of aluminium foil.

Trade Publications

A NEW leaflet issued by Darwins, Ltd., lists six qualities of high speed steel made by the Company, and provides a guide to typical applications of the various grades. Full details are also given of the procedures for forging, annealing, hardening, tempering and grinding.

THE latest publication of General Refractories, Ltd., takes the form of a folding leaflet, giving useful information on a number of aspects of the use of refractories. These include a chart for the rapid estimation of temperature gradients and heat losses through furnace walls, whether of a single material or a composite structure ; typical physical properties of General Refractories' products ; a table of temperature end points of pyrometric cones of Seger, American and German types ; and the approximate bending temperatures of Holderofts thermoscope bars.

GAS carburising is now firmly established as a means of increasing the surface carbon content of steel in order to caseharden it. In a new 12 pp. brochure, British

Furnaces, Ltd., describe various items of plant made by them for carrying out this process. These include an endothermic atmosphere preparation unit, batch and continuous furnaces, and handling equipment both inside and outside the furnace.

PUBLICATION No. 72 produced by W. C. Holmes and Co., Ltd., describes briefly the range of dust collection and control plant manufactured by the Company's Gas Cleaning Division. These comprise four distinct types of plant which cover the vast majority of industrial pollution products. These are the Holmes-Elex electrical precipitators, the Holmes-Schneible multi-wash system, the Holmes-Rothemuhle multi-cell cyclone dust collectors, and the Trion electronic air filters. Fuller details of each of these systems are given in separate publications, Nos. 69, 54, 68 and 67, respectively.

THE November, 1957, issue of *Close-Up*, the house magazine of Armstrong Whitworth (Metal Industries), Ltd., and Jarrow Metal Industries, Ltd., contains an essay by Mr. A. W. Scott of the latter Company, which won first prize in the British Steel Founders Association Prize Essay Competition. The title of the essay is "A Discussion of the Impact of Modern Methods of Production and Supervision on the Functions of the Foundry Foreman."

NORTHERN ALUMINIUM CO., LTD., have recently brought up-to-date one of their publications. This booklet, *Noral Products—Tables of Weights* is intended to provide a ready source of information on the weights of many of the aluminium products—sheet, corrugated sheet, plate, circles, bar, tubes and wire—manufactured by the Company. Designed for easy wall-mounting where required, the 11 in. × 8¼ in. thumb-indexed booklet is a useful reference for those who use aluminium in any of its many forms.

A RECENT George Kent publication (No. 150) is concerned with Kent instrument panels which are now available in two basic types. The plate-type is made in one section (up to 10 ft. in width) where the side rear and roof are normally welded in position. The unit-type (in cabin or non-cabin version) is used where the preference is for an assembly built up by combining the smaller sections of 1 ft. 3 in. or 2 ft. width depending on the overall panel-width requirements. Publication 986 illustrates an automatic-control panel for Highveld Power Station, South Africa.

ALTHOUGH metals are the traditional materials for making tools, epoxy resins offer certain advantages for reference tools in which stability and accuracy are the main requirements, and for press tools for short or moderate runs. Aero Research, Ltd., Duxford, Cambridge, have published a 32-page illustrated booklet describing the use of Araldite resins for various tooling purposes.

THE box-type of furnace is the original type of heat-treatment installation and has the widest application of any type of furnace. It is essentially a batch furnace and can be used for almost any industrial heating operation. An illustrated brochure issued by G.W.B. Furnaces, Ltd., discusses various features of the furnaces of this type made by the company, and refers to typical applications.

A PROFUSELY-ILLUSTRATED 24-page booklet entitled "Weight Control with Electron" has recently been issued by Magnesium Elektron, Ltd. It is a revised and enlarged edition of an earlier publication, and draws attention to the economics of weight saving in aircraft. Particulars are given of some of the principal magnesium alloys, especially those containing zirconium and thorium, by which such economy can be effected. It also includes alloys not mentioned in the earlier edition.

WITH the title "Everything for the Laboratory," a recent Griffin & George leaflet gives brief particulars and prices of a number of items of laboratory equipment, the two major ones being the Griffin-B.C.R.A. isothermal bomb calorimeter and the Griffin apparatus for the analysis of liquids and gases by vapour phase partition chromatography. A further new leaflet concerns metal laboratory furniture which Griffin & George handle in conjunction with Grundy Equipment, Ltd.

THE heavy demand for Wellman mobile machines, since their introduction in 1943, has led the Wellman Smith Owen Engineering Corporation, Ltd., to the production of certain standard models, designed and constructed in a wide range of capacities to meet most of the varying conditions encountered in the ferrous and non-ferrous industries. These machines comprise forging manipulators for handling ingots and billets into and out of reheating furnaces and under the forging hammer or press; furnace box chargers of both the bar-turn and push-discharge types; and handlers for charging and discharging furnaces and carrying materials, such as ingots, billets, blooms, tyre or wheel blanks and plates to presses, hammers, rolling mills, etc.

IN addition to its usual brief items concerning novel uses of aluminium, the October 1957 issue of *Aluminium News* contains illustrated features dealing with the use of aluminium sliding roofs for box cars on the French National Railways and aluminium honeycomb used in aircraft for its high strength : weight ratio. A further article deals with the explosions arising by the spilling of molten metal into water or on to wet surfaces, and presents the findings of an investigation by the Aluminum Company of America.

Books Received

"Brittle Behaviour of Engineering Structures." By E. R. Parker. 323 pp. inc. author and subject indexes. New York and London, 1957. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 28s. net.

"The Science of Engineering Materials." Edited by J. E. Goldman. 528 pp. inc. name and subject indexes. New York and London, 1957. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 96s. net.

"Cost Finding in the Non-Ferrous Industry." 84 pp. and 74 pp. of examples. Birmingham, 1957. The British Non-Ferrous Metals Federation. 42s.

"Gas Turbine Materials." By G. Lucas and J. F. Pollock. 163 pp. London, 1957. Temple Press, Ltd. 25s. net.

"Engineering Metallurgy." Part I: "Applied Physical Chemistry." By R. A. Higgins. 404 pp. London, 1957. The English Universities Press, Ltd. 25s. net.

"Coke-Burning Appliances Handbook." 410 pp. London, 1957. The Gas Council. 15s.

"Metallurgical Reviews." Vol. 1, 1956. 522 pp. The Institute of Metals. Available only by annual subscription of 42s. 6d. or $6.50, post free, including a cloth binding case.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
DECEMBER, 1957. Vol. LVI, No. 338

The Analysis of Silver Solder Alloys

By E. Jackson
The Sheffield Smelting Co., Ltd.

An accurate and relatively quick method is described for the analysis of silver solders, involving a cation exchange chromatographic separation of cadmium followed by an anion exchange separation of zinc. Both elements are determined subsequently by titration with ethylene diamine tetra acetic acid (E.D.T.A.). The silver and copper are determined by standard methods.

THE standard chemical methods of analysis employed for quaternary silver solders containing 20–80% silver, 10–45% copper, 1–25% cadmium and 10–35% zinc are long, tedious and unpleasant, involving double or treble sulphide separations of cadmium and zinc.[1, 2] Now that ion exchange techniques and complexometric titrations have become so widely applied in analysis, it was thought that together they might offer a relatively short and simple procedure for silver solders.

Baggott and Willcocks[3] and Hunter and Miller[4] separated zinc from cadmium by means of anion exchange resins. In both cases the recovery of the cadmium from the resin was difficult, and neither method appeared to be applicable. A further anion exchange separation of these metals[5] had the disadvantage of sodium chloride in the eluting agent. However, a cation exchange chromatographic separation by Yoshino and Kojima[6] appeared to offer a suitable basis for possible extension to these alloys. The principle of this separation was a preferential elution of cadmium from zinc and copper after take-up of these metals on a cation resin. This was based on previous work by Wickbold[7] and Sweet, Rieman and Benkenkamp.[8]

Yoshino and Kojima showed that the adsorption characteristics of copper and zinc were almost identical over a wide range of hydrochloric acid concentration, while the adsorption of cadmium decreased rapidly, relative to copper and zinc, in concentrations above 0·2 N hydrochloric acid. They confined their work to the determination of small amounts of cadmium in copper and zinc and small amounts of copper and zinc in cadmium, but it seemed likely that the principle could be applied to the separation of macro amounts of these metals as encountered in silver solders.

EXPERIMENTAL

The Separation of Cadmium

Experiments were carried out to determine whether amounts of cadmium up to 125 mg. could be quantitatively separated from 100 to 400 mg. of copper and zinc, corresponding to 0·5 g. alloy trials, by suitable variation of column dimensions and concentration of the eluting acid.

After preliminary tests on column length, a dilute nitrate solution containing 20 mg. cadmium, 225 mg. copper and 155 mg. zinc was passed through a cation exchange resin column (1·6 × 35 cm. Zeo-Karb 225 (H))

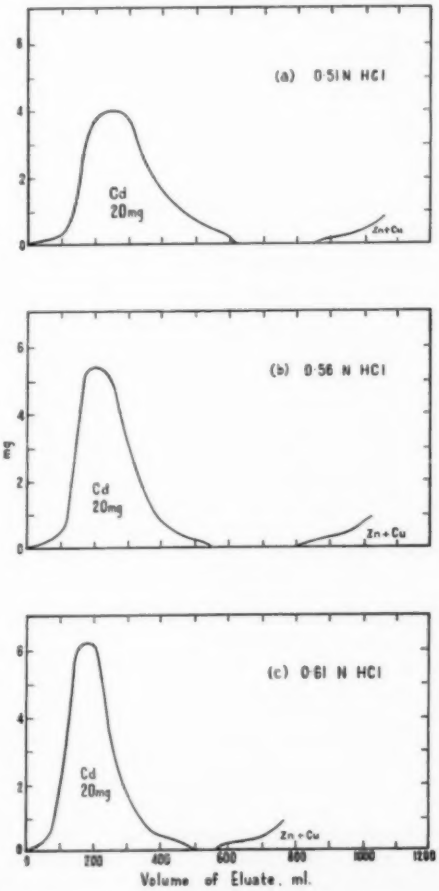


Fig. 1.—Influence of hydrochloric acid concentration on elution of cadmium.

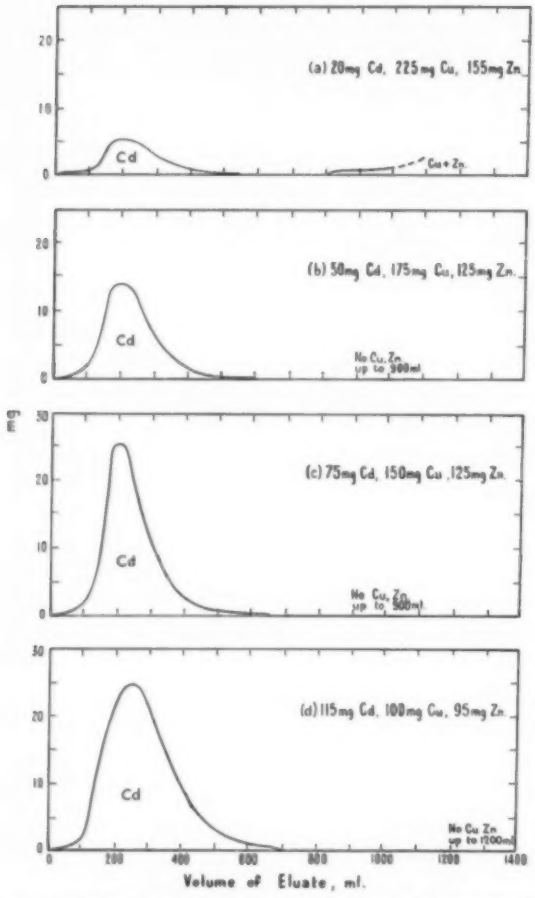

(a) 20mg Cd, 225mg Cu, 155mg Zn
Cd
Cu + Zn
(b) 50mg Cd, 175mg Cu, 125mg Zn
Cd
No Cu, Zn up to 500ml
(c) 75mg Cd, 150mg Cu, 125mg Zn
Cd
No Cu, Zn up to 500ml
(d) 115mg Cd, 100mg Cu, 95mg Zn
Cd
No Cu Zn up to 1700ml
mg
0 200 400 600 800 1000 1200 1400
Volume of Eluate, ml.

Fig. 2.—Elution of increasing amounts of cadmium with 0·56 N hydrochloric acid.

and the metals taken up. The resin was then eluted with 0·51 N hydrochloric acid and the cadmium determined in the eluate which was collected in 50 ml. fractions. This was repeated for other hydrochloric acid concentrations of the eluent, and the effect of this variation on the elution of the cadmium, copper and zinc is shown in Fig. 1. From this it was concluded that 0·56 N hydrochloric acid was the optimum concentration for the efficient separation of such amounts.

0·56 N acid was then used for the elution of larger quantities of cadmium from correspondingly different amounts of copper and zinc after take up on a similar cation column. The elution curves for these are shown in Fig. 2. It was seen from these graphs that 700 ml. of eluent was sufficient to remove all the cadmium in each case without contamination by any copper or zinc. Also, the interval between the last fraction containing cadmium and the first containing copper or zinc increased with decreasing amounts of copper and zinc, as had also been shown by Yoshino and Kojima.[6] This suggested that the hydrochloric acid concentration of the eluting agent could be safely increased for eluting amounts of cadmium greater than 100 mg., thus reducing the volume required. This was confirmed, Fig. 3 showing the elution curve using 0·66 N hydrochloric acid for 115 mg. cadmium (*cf.* Fig. 2*d*).

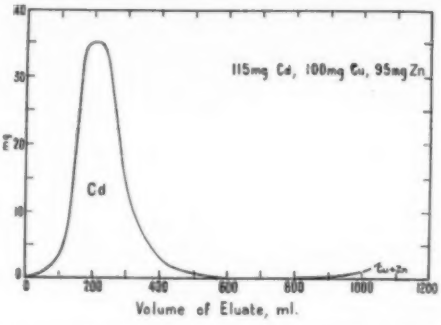


Fig. 3.—Elution with 0·66 N hydrochloric acid.

For the complexometric titration of the cadmium it was found necessary to evaporate the eluate to dryness first, and re-dissolve with 10 ml. of diluted nitric acid (1 : 49) before adding the buffer and indicator and titrating with ethylene diamine tetra acetic acid.

The Separation of Zinc

The zinc and copper could readily be eluted from the cation resin using 2 N hydrochloric acid. However, it was found convenient at this stage to make use of the fact that zinc is strongly retained by anion exchange resins in acid concentration of about 2 N hydrochloric acid.[9] Thus, by connecting an anion exchange column of suitable dimensions to the outlet of the cation column and eluting the combined columns with 2 N hydrochloric acid, only the copper issued from the anion resin while the zinc was retained. Tests showed that there was a sufficient lead of the 2 N hydrochloric acid front over the first fraction containing zinc to prepare the anion resin for zinc take-up. To ensure complete elution of the copper an additional wash of N hydrochloric acid was used, as employed by Rees and Hartley.[10] The volume used was sufficient to complete the removal of the copper without loss of any zinc from the anion resin.

The zinc was most readily eluted from the column, after disconnecting it from the cation exchanger, by means of N nitric acid. This solution could be neutralised directly with ammonium hydroxide and titrated with ethylene diamine tetra acetic acid after the addition of buffer and indicator.

Impurities such as iron, aluminium, manganese and nickel, if present, were eluted with the copper, and could be determined in the filtrate after electrolytic separation of the copper.

METHOD

Reagents

Cation Exchange Resin : Zeo-Karb 225 (H).

Anion Exchange Resin : Amberlite I.R.A. 400 (Cl).

0·1 *N E.D.T.A.* : Dissolve 18·76 g. di-sodium salt of ethylene diamine tetra acetic acid in water and dilute to 1 litre. 1 ml. = 3·28 mg. zinc.

0·05 *N E.D.T.A.* : Dissolve 9·38 g. di-sodium salt of ethylene diamine tetra acetic acid in water and dilute to 1 litre, 1 ml. = 2·82 mg. cadmium.

Standard Zinc Solution : Dissolve 1 g. of high purity metal in 10 ml. diluted nitric acid (1 : 1) and dilute to 1 litre. 1 ml. = 1 mg. zinc.

TABLE I.—DETERMINATION OF CADMIUM AND ZINC IN SYNTHETIC SILVER SOLDERS.

	Composition of Synthetic Alloys				Sample Weight	Found by Proposed Method						
	Ag%	Cu%	Cd%	Zn%	g.	Cd%			Average Cd%	Zn%		Average Zn%
1.	20	45	4	31	0·5	3·97	4·00	4·02	4·00	31·04	31·01	31·03
2.	30	35	10	25	0·5	10·04	9·97	10·08	10·03	24·97	25·06	25·02
3.	30	30	15	25	0·5	14·97	15·06		15·02	24·94	25·03	24·98
4.	38	20	23	19	0·5	23·01	22·98	22·99	22·99	19·03	19·00	19·02

Standard Cadmium Solution : Dissolve 1 g. of high purity metal in 10 ml. diluted nitric acid (1 : 1) and dilute to 1 litre. 1 ml. = 1 mg. cadmium.

Buffer Solution A : Dissolve 5 g. ammonium chloride in water, add 40 ml. of 0·88 s.g. ammonia solution and dilute to 1 litre.

Buffer Solution B : Dissolve 25 g. ammonium chloride in water, add 133 ml. of 0·88 s.g. ammonia solution and dilute to 1 litre.

Indicator : Dissolve 0·5 g. Eriochrome Black T in 100 ml. of 30% iso-propyl alcohol in water.

Procedure

Dissolve 0·5 g. of alloy in 3 ml. of diluted nitric acid (1 : 1). Dilute to approximately 125 ml. and precipitate the silver chloride with 10 ml. of diluted hydrochloric acid (1 : 9). Filter, wash, and determine the silver by a standard method.

Mix the filtrate and pass through a cation exchange column (1·6 × 35 cm., Zeo-Karb 225 (H)), and wash with 150 ml. of distilled water. Discard the effluent. Elute the cadmium by passing 700 ml. of 0·56 hydrochloric acid (or 600 ml. of 0·66 N hydrochloric acid if the cadmium content is greater than 20%) through the resin. When the first 50 ml. of eluate has been collected, arrest the flow for 15 minutes and then continue elution at the rate of 3 to 4 ml. per minute. Evaporate the total solution to dryness and then dissolve with 10 ml. of diluted nitric acid (1 : 49). Add 20 ml. of buffer solution A, dilute to approximately 50 ml., and titrate with 0·05 N E.D.T.A. solution using Eriochrome Black T as the indicator. Standardise the E.D.T.A. solution with 50 ml. aliquots of the standard cadmium solution under identical conditions.

Connect an anion exchange resin column (1·6 × 18 cm., Amberlite I.R.A. 400 (Cl)) directly to the outlet of the cation column and elute with 350 ml. of 2 N hydrochloric acid. When 50 ml. of eluate has collected, arrest the flow for 15 minutes and then continue at the rate of 3 to 4 ml. per minute. Complete the elution of the combined columns with 250 ml. of N hydrochloric acid. Evaporate the total copper eluate to fumes with 10 ml. of diluted sulphuric acid (1 : 1), and separate the copper electrolytically. Analyse the filtrate for impurities such as iron and nickel if required.

Disconnect the anion column and elute the zinc with 300 ml. of N nitric acid at the rate of 3 to 4 ml. per minute, with an arrest of 15 minutes after 50 ml. has passed through.

Neutralise the zinc eluate with diluted ammonium hydroxide (1 : 1) using methyl red, and add 2 ml. of buffer solution B. Add Eriochrome Black T indicator and titrate with 0·1 N E.D.T.A. solution. Standardise the E.D.T.A. using 100 ml. aliquots of the standard zinc solution under identical conditions.

Results

The proposed method was used to determine cadmium and zinc in a number of synthetic silver solders covering a range of composition. The results of these analyses are shown in Table I.

Discussion

Compared with the standard method of analysis, the proposed method gives very accurate cadmium and zinc figures with a minimum of operations. It can be applied with advantage to the analysis of other alloys containing cadmium, or cadmium and zinc, such as cadmium-copper for telephone and trolley wires, cadmium-nickel and cadmium-silver-copper bearing alloys, and cadmium-zinc solders.

Acknowledgment

The author wishes to thank the Directors of The Sheffield Smelting Co., Ltd., for permission to publish this paper

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Extrusion Press for Museum

THE Delta Metal Co., Ltd., have presented to the Birmingham Museum of Science and Industry a 650 ton extrusion press. When this press was first put into production, there was no muffle to reheat the billets. The casting furnaces were close to the press, and after a cap had been fitted to one end of the container, the container was turned into an upright position. Next a crucible of molten metal was conveyed by overhead runway and poured direct into the container. After a short time, to enable the metal to solidify, the container was turned into the horizontal position, the cap removed, the dieholder carriage wound into position and the press was ready to extrude the billet. If the centre of the billet was still molten, as very often happened, there was a shower of molten metal down the channel. The production, therefore, depended upon the number of billets the casters produced.

Later, the method of having a muffle to obtain more uniform production, with more or less standard temperature was introduced. This was not easy to maintain, as the muffle was coal fired and a breakdown on the press very often resulted in the billets being melted in the muffle.

This extrusion press was first put into production at Lionel Street in 1897, and transferred to its present position in 1898. The output at the start was about ten extrusions per day. Before transferring the press to the Museum, the company arranged a special demonstration run so that a sound film record could be made of the process.

Assessing Surface Finish

A New Interference Microscope

AN instrument developed to meet the stringent modern demands in assessment and control of surface finish has recently been introduced by C. Baker of Holborn, Ltd. Interference microscopy is used with a system based on a modification of that devised by Mirau. The new instrument is not intended to replace the better known methods of assessing surface finish, such as recording stylus-operated devices. However, it has a number of advantages not available in the conventional instruments, and it is thought that it will be complementary to existing methods.

Features of Interest

One of the features of the instrument is the provision of facilities for visual assessment of an area of the work to be examined, in contrast to the limitations of point contact. With a little practice it is possible to assess a surface to about one micro-in. at a glance, which is much more rapid than conventional methods of comparable accuracy.

The design of the casing and mounting of both the specimen table and the microscope proper provides the stability necessary for accurate work with dimensions less than one millionth of an inch. The system of mounting the work and moving it below the objective is very simple and provides rapid, accurate setting. It is hand operated and has immediate response.

The optical system uses only one objective, instead of the more usual pair. Another feature of the optical system is that the division and recomposition of the light beam is confined to the small space between the objective and the specimen. Greater optical accuracy is thus achieved with simplified and, therefore, less expensive equipment.

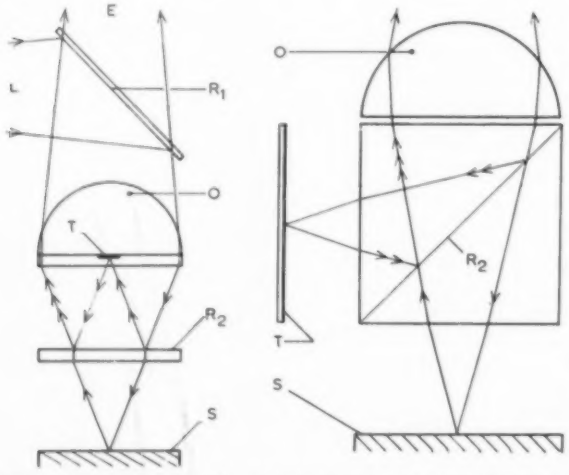


Fig. 1.—Diagrammatic representation of the objective systems from the original by Mirau. The arrangement on the left is used for × 40 and that on the right for × 10 magnification. The function is the same in both, and the same notation is used relative to the text.

The unit of measurement used is the wavelength of the green band of the spectrum, and is therefore constant. The light is derived from a special mercury lamp, and the whole of the equipment, including the choke, etc., is housed in the one case, the only external detail being a power lead to the ordinary mains supply.

Since the light used is the source of the unit of measurement, the instrument requires no external calibration and is unvarying in its accuracy. Filters are fitted and controlled by selector knob. A corresponding control on the other side of the instrument front varies the aperture for contrast when viewing the specimen.

For photomicrography, the equipment includes a simply operated camera using 35 mm. film. To change from visual inspection to camera setting, a single motion of a knurled disc turns a prism in the system. The camera lens is fixed in the microscope and normally covered, and the camera body, carried in clips in the case door when not in use, is simply attached and secured by screw ring.

Construction

To obtain the required degree of stability, a one-piece cast aluminium body is used. The doors, hung on this case provide protection for the instrument. The microscope unit is self-contained and travels vertically over a sufficient distance for focusing on steel balls running in long vee-ways: the housing ways are inserted in the case. A counterpoise weight in the back of the case controls the motion of the object table. In effect, the microscope is in balanced suspension, a system which has been found to provide the necessary stability for operation. The arrangement is not temperature-critical as is the case with normal mountings, but, although special temperature and vibration control are not necessary, it must be remembered that the instrument is a delicate one.

It is necessary to provide a slight tilt for the optical system to generate the interference fringes. To this end, the table is carried on a ball type support unit. The main table carrier is a yoke, which runs vertically in long guideways in the housing and has a bowl-form coaxial with the microscope. The form carries a hemispherical insert which may be universally tilted, the mating faces of the unit being optically-lapped and polished. The insert carries a top plate of hardened steel which supports the specimen table: this is also a hardened and optically-lapped steel plate.

To obtain the required movement, a special silicone grease is applied between the mating faces. The particular grease is selected for a number of properties, including temperature stability. The main feature of the grease, however, is that it does not allow the table to creep as it is set in position beneath the objective. Adjustment of the specimen is made by sliding the table on the carrier. The tilting action, which may be clamped when set, allows adjustment of the fringe spacing as seen through the eyepiece.

The table is 7 in. in diameter, and when fully lowered

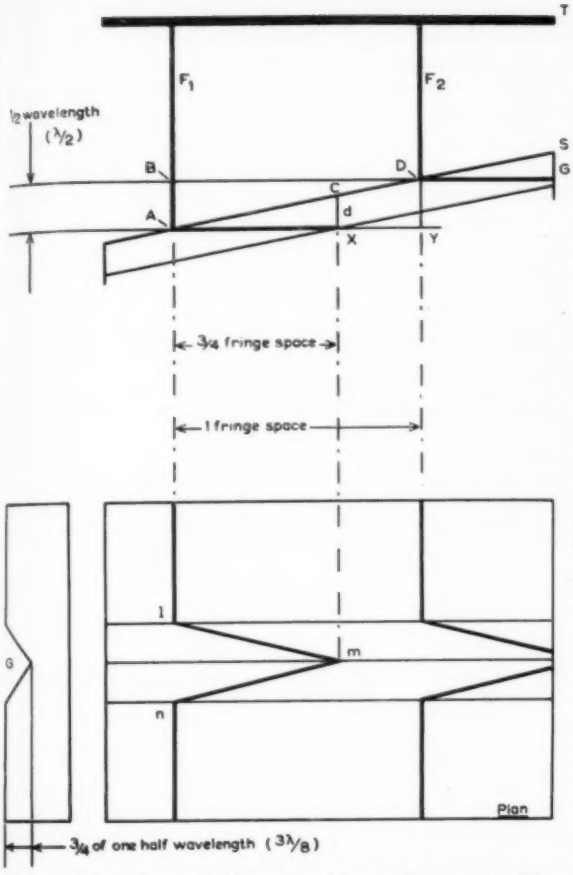


Fig. 2.—Elevation and plan of a plane surface crossed by a groove, showing the method of measurement using interference fringes.

there is 5 in. clearance between the table top and the objectives.

Optical System

The fringe pattern, already mentioned, is analagous to the Newton's fringes that are so well known. In effect, the microscope system produces the same conditions as obtain when a test glass is placed in contact with a flat specimen that reflects light, but in this case there is no contact between the optical unit and the specimen.

The low and high power objectives are shown diagrammatically in the attached drawing, Fig. 1, the two systems being the same in function. Light from the lamp L is reflected by a semi-reflecting surface R_1 to the back of the objective lens O, which focuses the light upon the specimen surface S. In passing from the objective to the specimen surface, the light encounters a second semi-reflecting surface R_2, which reflects some of the light back to illuminate an optically-worked metal-coated reference surface T. Further reflection from this surface results in its image coinciding with the image of the specimen S seen in the eyepiece.

The spot T and the specimen S are optically equidistant from R_2. The effect obtained is therefore the optical equivalent of the reference plane T being placed in contact with the specimen surface S. An interferometric comparison occurs and the recombination of light from S and T produces the fringe pattern.

It is necessary for the reflectivity of the reference T to suit the specimen. Two objectives are accordingly made available ; one suits metallic surfaces and the other is suited to paints, ceramics and so on. Thus, a total of four objectives will provide magnifications of $\times$ 400 and $\times$ 100 for metallic and non-metallic surfaces. All four can be supplied mounted on a conventional changer.

The measuring principle depends upon two well established facts. First, all points along the surface intersected by one fringe are equidistant from the reference surface. Thus, the fringe follows a path that provides a contour map of the specimen surface as indicated by l m n in Fig. 2. Secondly, the difference in level of the specimen between any two fringes is invariably one half of the wavelength of light chosen for illumination. In this case the wavelength of green light (λ) is 0·546 micron or 21·6 micro-in. Referring to Fig. 2. to find the depth of the groove it is only necessary to compare the distance AX with the fringe spacing AY ; this ratio equals the ratio of the depth at X to half the wave length of light used. This may be written :—

$$\frac{AX}{AY} = \frac{d}{\frac{1}{2}\lambda} \text{ or } d = \frac{\frac{1}{2}\lambda AX}{AY}$$

where d is required depth and $\frac{1}{2}\lambda$ is 0·273 micron or 10·8 micro-in.

It will be seen that, by visual inspection, it is possible to estimate surface irregularities to 0·1 of a fringe interval, or about one micro-in.

Measurements

From photomicrographs it is only necessary to establish the ratio AX/AY and multiply by the half wavelength to have a precise measurement of the depth or height of any irregularity. The operation is aided by adjusting the tilt of the table, which varies the spacing of the fringes. The actual dimension is in no way

Fig. 3.—Interferogram of turned aluminium alloy, showing grooves and areas where the metal has been chipped-out.

changed by tilting, and the accuracy of the system remains constant, but it is sometimes easier, when the surface is poor, to identify one fringe.

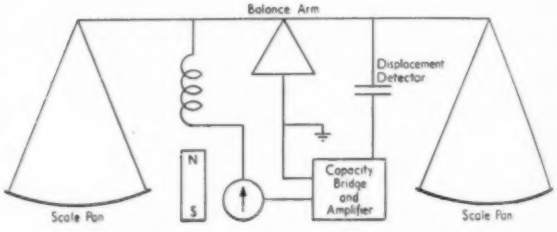
Differentiation between grooves and ridges in the specimen is simple. The fringes run against the tilt of the table when following a groove, and, conversely, they run with the tilt of the table when meeting a ridge. To ensure proper interpretation of photographs, a mark in the camera system is transferred to the negative to provide orientation. It is then only necessary to make a note of the direction of tilt, forward or backward, when taking the picture to be certain of the results. The instrument can be applied to plane, spherical or cylindrical surfaces with equal facility. Spherical surfaces show ring fringe patterns and cylinders show parallel or elliptical patterns, according to the orientation of the work. Inspection of internal surfaces is carried out by the now well-established practice of taking plastic-film replicas.

Quick-Acting Balance

Useful Aid to Routine Analysis

ALTHOUGH the analytical balance has been developed through the years into an instrument of high precision, it has certain disadvantages for weighing operations in which very large numbers of weighings, usually repetitive, are made daily. In these circumstances the time taken on each operation represents a considerable cost for labour. Furthermore, when several hundred weighings are performed daily, the knife-edges and planes in a balance wear out comparatively quickly, even when the balance is handled with care, and frequent—and expensive—maintenance becomes necessary.

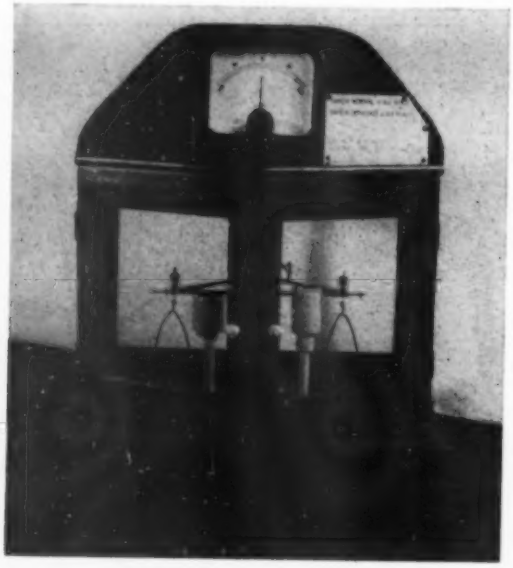
To overcome these two problems, the Physics Department of the British Iron and Steel Research Association has developed a quick-acting balance with which it should be possible to make about three times as many weighing operations per day as with a normal analytical balance. Although its initial cost will be higher, the quick-acting balance will require less expensive maintenance. It has been designed specifically for a maximum load of 5 g. with an accuracy of 1 mg. These limits can, however, be varied appreciably, with a limiting accuracy of one part in 10,000 of the maximum load.



Schematic diagram of the quick-acting balance.

The balance has its beam suspended at its centre of gravity, so that no restoring force is applied if the beam is displaced. When a load is placed on one pan, the resulting movement of the beam is translated into an electric current, which is used to generate a restoring force in a coil and magnet system. The beam quickly takes up an equilibrium position in which these two forces are exactly balanced. Under these conditions, the current which gives rise to the restoring force is directly proportional to the load, and can be displayed on a suitably calibrated meter. As a display accuracy of one part in 10,000 is not possible on a single instrument, the meter has two ranges. The first, giving a range of 5 g. with an accuracy of 50 mg., is used for a coarse weighing. Conventional weights (to the nearest 100 mg.) are selected in one operation as a counter-weight. The residue can then be displayed on the fine range (100 mg. to an accuracy of 1 mg.). Using this technique, a weighing operation can be carried out in from 15 to 20 seconds.

The beam pivot takes the form of a cross-spring hinge. At maximum displacement it introduces a torque equivalent to a load of about ¼ mg. in one pan. This hinge, of comparatively robust construction, has a long life. The beam can be left 'live,' i.e. it can always be free to swing and need not be arrested in the normal way before loads are added to or removed from the pans.

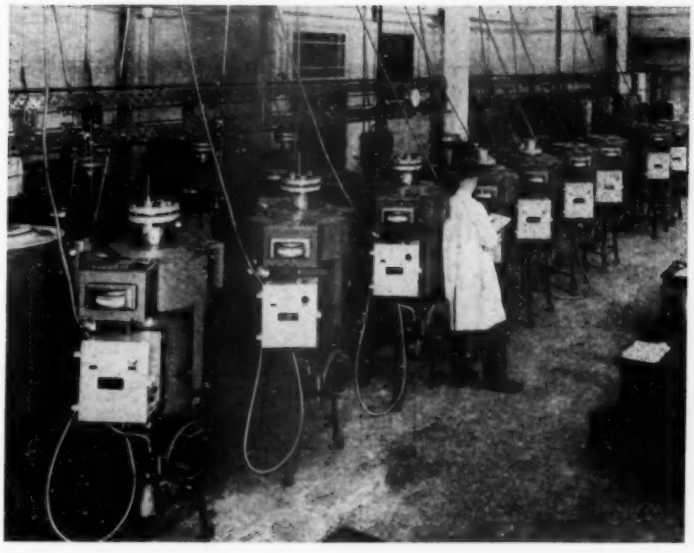


Laboratory prototype.

THE Magnetic Equipment Co., Ltd., have appointed Messrs. La Thermo-Technique S.P.R.L., of 52, Avenue De L'Hippodrome, Brussels, as their sole representatives for Belgium, in place of Messrs. Europe Technic S.P.R.L., of Charleroi.

Creep Tests on Materials for Gas-Cooled Reactors

New Research Equipment at G.E.C. Atomic Laboratories



Battery of twelve units installed in the laboratories of the G.E.C. Atomic Energy Division for preliminary creep and stress-rupture tests on nuclear reactor materials.

NEW research equipment designed to provide preliminary creep and stress-rupture data on metals and alloys in gaseous atmospheres at high temperatures and pressures has recently been installed in the materials research laboratory of the G.E.C. Atomic Energy Division at Erith, Kent.

Twelve creep-units have already done valuable basic work in investigating the properties of magnesium alloys widely employed for fuel element cans, in carbon dioxide atmospheres. They can readily be converted for future work to deal with other materials in other gases. The equipment has been installed to meet the requirement for applied research facilities beyond the range of normal metallurgical laboratory equipment. This equipment arises from the urgency of the British nuclear power programme, which demands that investigations be carried out at a much greater pace than is usually imposed on metallurgical work.

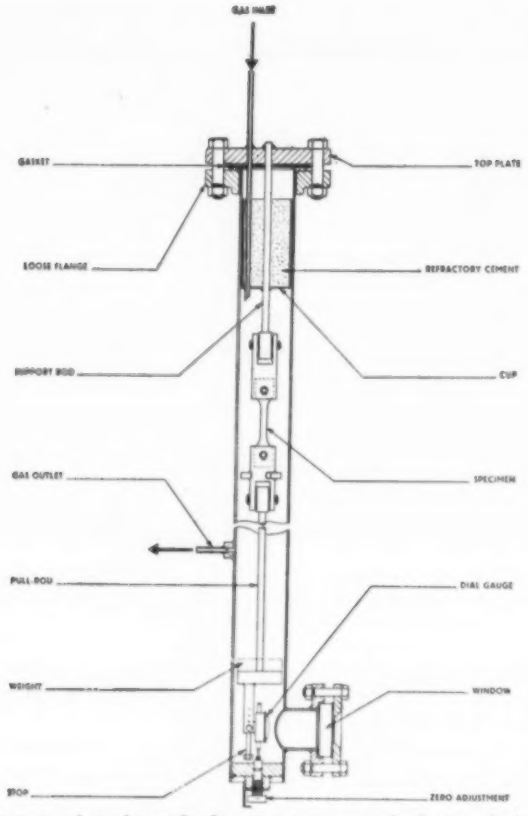
Machines for carrying out creep tests in air are standard items of laboratory equipment, and it is comparatively easy to adapt such machines for operation in other atmospheres by enclosing the test specimen in a gas-tight vessel through which the pull-rod passes via a gas-seal. This arrangement can, however, be used only at atmospheric pressure, and while the results obtained can be of definite value, it is highly desirable to investigate the effects of gas pressures such as prevail in a reactor circuit.

The battery of units now installed at Erith was designed for a specifically limited purpose. It is not claimed that it can be used for a complete investigation into the creep behaviour of materials under reactor-operating conditions. Within the time-factor imposed, however, it does provide an efficient means of obtaining, very rapidly, a broad assessment of the suitability of materials for reactor service. More detailed investigation can then be undertaken on materials which pass this preliminary test. Within these limits, the equipment has proved capable of remarkably consistent and reproducible results which are of great value in the implementation of a speedy and efficient nuclear power development programme.

In this new equipment, the specimen, the whole of the stressing apparatus and the associated extensometer are enclosed in a vertical cylindrical pressure vessel. This, in turn, is enveloped along part of its length by an electric furnace. The body of the pressure vessel, which is of $\frac{3}{16}$ in. thick stainless steel, is approximately 5 ft. long and has an internal diameter of 4 in. At its open upper end it is provided with a machined facing flange. The top plate of the vessel is bolted down to a loose flange slipped over the vessel body, a Klingerite gasket being inserted between the top plate and the facing flange to ensure gas-tightness.

The upper end of the support rod, from which the specimen is suspended, is welded to the centre of the top plate, while its lower end is provided with a pivoted coupling, a similar coupling being fitted to the top of the pull-rod. Alternative couplings are available, so that specimens of either rectangular or circular cross-section can be used. A cylindrical cup, which is a loose fit in the pressure vessel, is welded to the support rod between the top plate and the coupling, and is filled with refractory cement so as to provide heat insulation above the operating section.

The loading weights are mounted on a plate welded to the lower end of the pull-rod. To the underside of this plate is attached a bracket carrying a dial gauge, whose operating head rests on the end of a bolt passing through the bottom plate of the pressure vessel via a rubber gas-seal. The bolt serves as a zero-setting device for the gauge. The gauge reading can be observed through a pressure- and heat-resistant glass window mounted between soft rubber gaskets in a tube welded into the side of the pressure vessel. A stop is provided beneath the gauge mounting to prevent excessive travel of the pull-rod, which might damage the gauge in case of rupture of the specimen.



Cross-section through the pressure vessel of one of the units.

Gas is admitted to the pressure vessel through a tube of ¼ in. internal diameter passing downwards through the top plate and the refractory cement plug. A gas outlet tube, of the same diameter, is welded into the side of the vessel below the operating section.

The 4 kW. electric furnace is built in two sections, and can be split by unbolting two vertical clamping plates, thus allowing the pressure vessel to be removed. The nickel chromium heating elements are carried in slots in the inner faces of bricks of high-temperature insulating material which are assembled in the form of a hexagon surrounding the pressure vessel, the space between the element bricks and the furnace casing being filled with refractory cement. The vertical wound length of the elements is 21 in. which gives an entirely satisfactory temperature distribution in the region of the specimen.

The two heating elements, one in each half of the furnace, are connected in parallel to a 240 volt, single-phase, 50 cycle supply, the leads being brought out, through the element bricks, to terminal blocks in ventilated chambers built round the top of the furnace casing. Connected in the supply circuit are a main contactor, housed in a cubicle mounted on the furnace casing, and a Variac. The latter is used for coarse regulation of the furnace supply, particularly during the warming-up period.

During normal operation, two Chromel-Alumel thermocouples are employed. One is mounted directly on the specimen, and is usually connected to a recording instrument, its leads being taken upwards through the gas inlet tube, from which they issue through a gas-seal. The second is mounted adjacent to the furnace winding and is connected to an Electroflo temperature controller housed in a louvre-ventilated casing built into one of the two terminal chambers. With this arrangement, extremely sensitive regulation of specimen temperature has been achieved.

When the stressing apparatus, with the test specimen mounted in position, has been lowered into the pressure vessel, the top plate is sealed down. The vessel is then thoroughly flushed with the gas being used as the test atmosphere before being brought up to pressure. The supply to the furnace is adjusted, by means of the Variac, to raise the temperature of the specimen rapidly to the required value, and it is then maintained at this level, to a fine degree of accuracy, by the temperature controller.

When stable conditions have been established, extensometer readings are taken at suitable intervals, the results being plotted as percentage creep against time. The total duration of the test varies according to the particular requirements, but is normally between 150 and 1,500 hours.

Briton Appointed to U.S. Chemical Metallurgy Chair

Dr. J. H. Schulman, a Fellow of Trinity Hall and Reader in Surface Chemistry at Cambridge University, has been appointed to the Stanley-Thompson Chair of Chemical Metallurgy recently established by the Inter-Nickel Company, Inc., at Columbia University. The chair is so named in honour of Mr. R. C. Stanley, Chairman of International Nickel until his death in 1951, and Dr. J. F. Thompson, his successor, former students of Columbia School of Mines. The chair is endowed by a grant of $350,000 and the company made a gift of $75,000 for special expenditures incidental to the establishment. In making the grant, Mr. H. S. Wingate, President of International Nickel, explained that the company wished to support fundamental research in the surface chemical and physical aspects of many problems in extraction metallurgy.

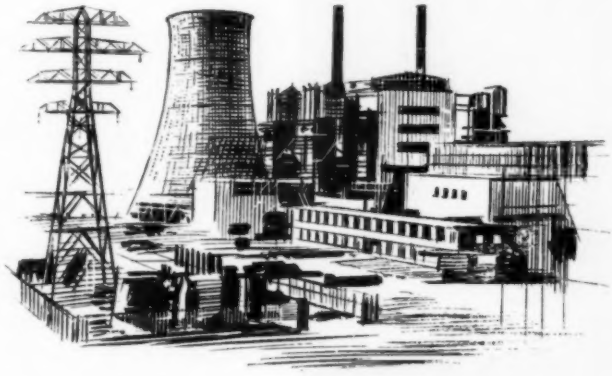
Castrol Enters Chemical Industry

A further expansion of the trading interests of the Wakefield Group of Companies, headed by C. C. Wakefield & Co., Ltd., is announced. For many years, the Wakefield Group has been a large scale producer of chemical additives for the lubricating oils of its own manufacture. Certain of these additives will, in future, be available to the outside market and it is also the Group's intention to manufacture and market other chemical products not necessarily connected with lubricants. The marketing of the chemical products of the Group will be carried out through its Member Company, Edwin Cooper & Co., Ltd., 43, Grosvenor Street, London, W.1.

Change of Address

Griffin & George, Ltd., the laboratory furnishers, announce that the address of their sales office and warehouse for the Birmingham area is now Frederick Street, Birmingham 1, (CENtral 2552). Also, the telephone number of their Edinburgh office at Johnston Terrace is now CALedonian 4868.

ROTOR SHAFTS



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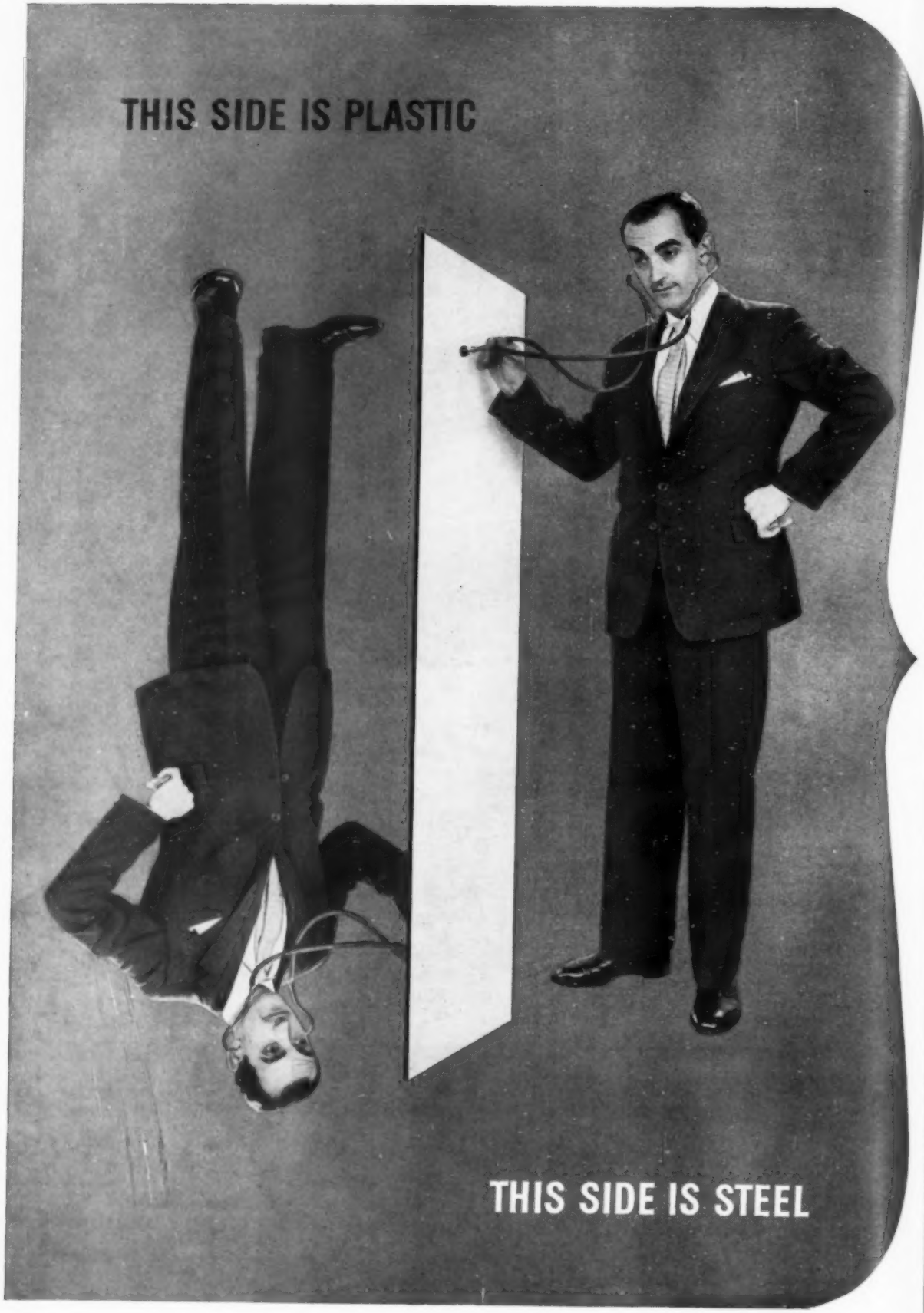
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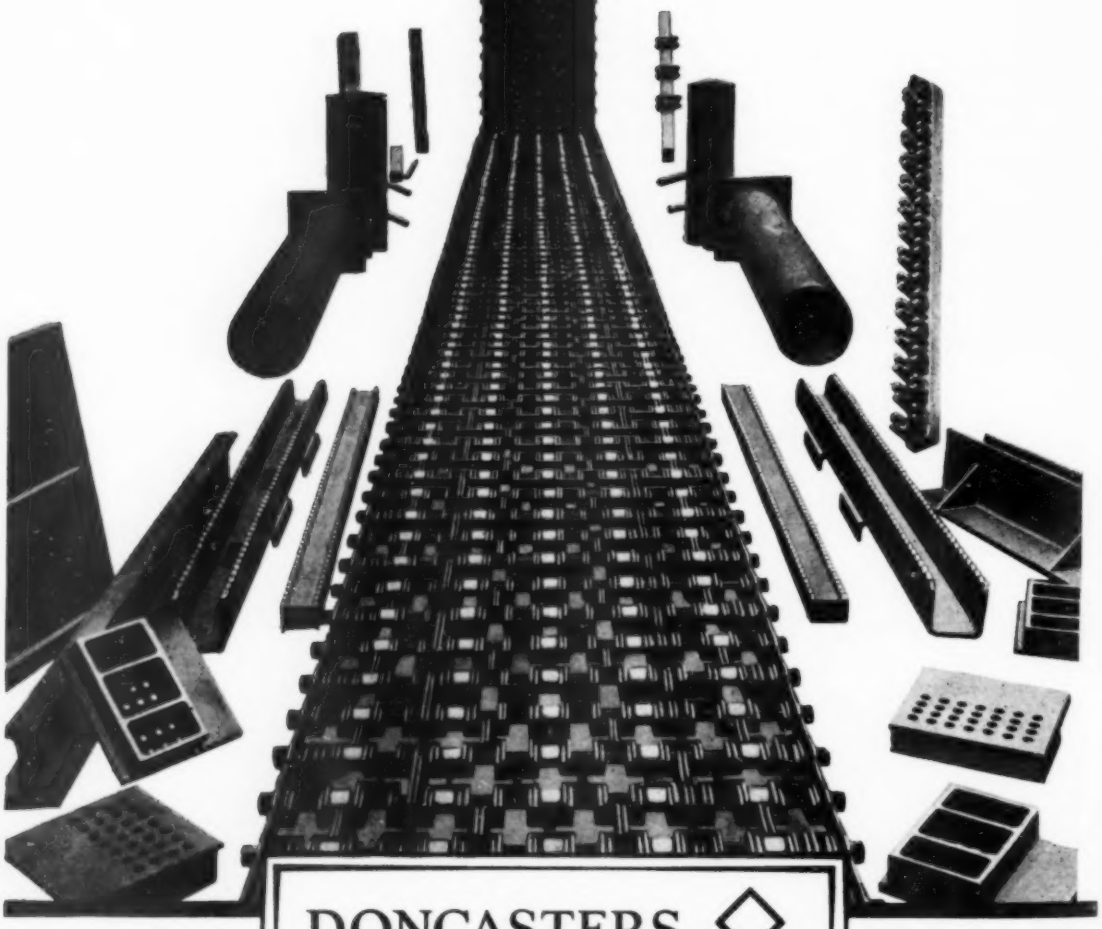

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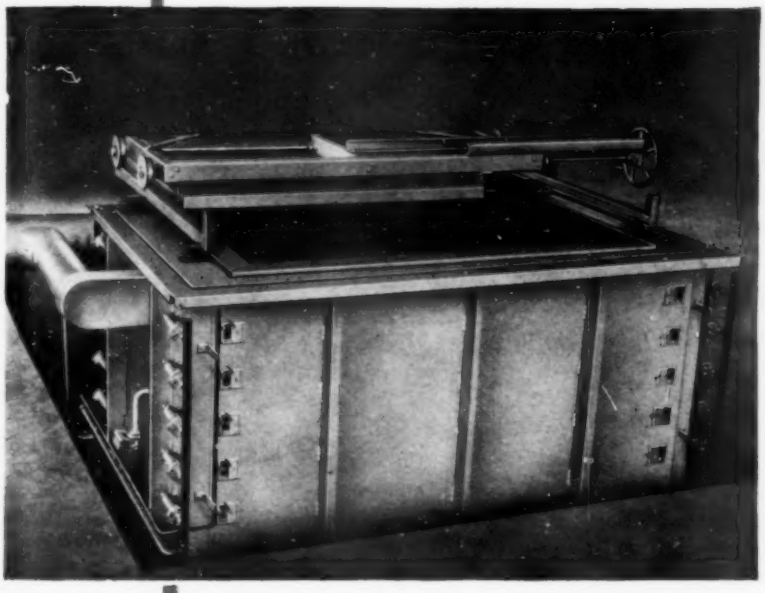

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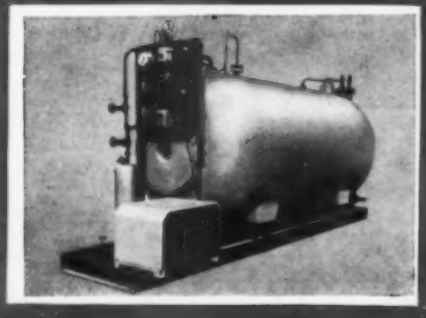

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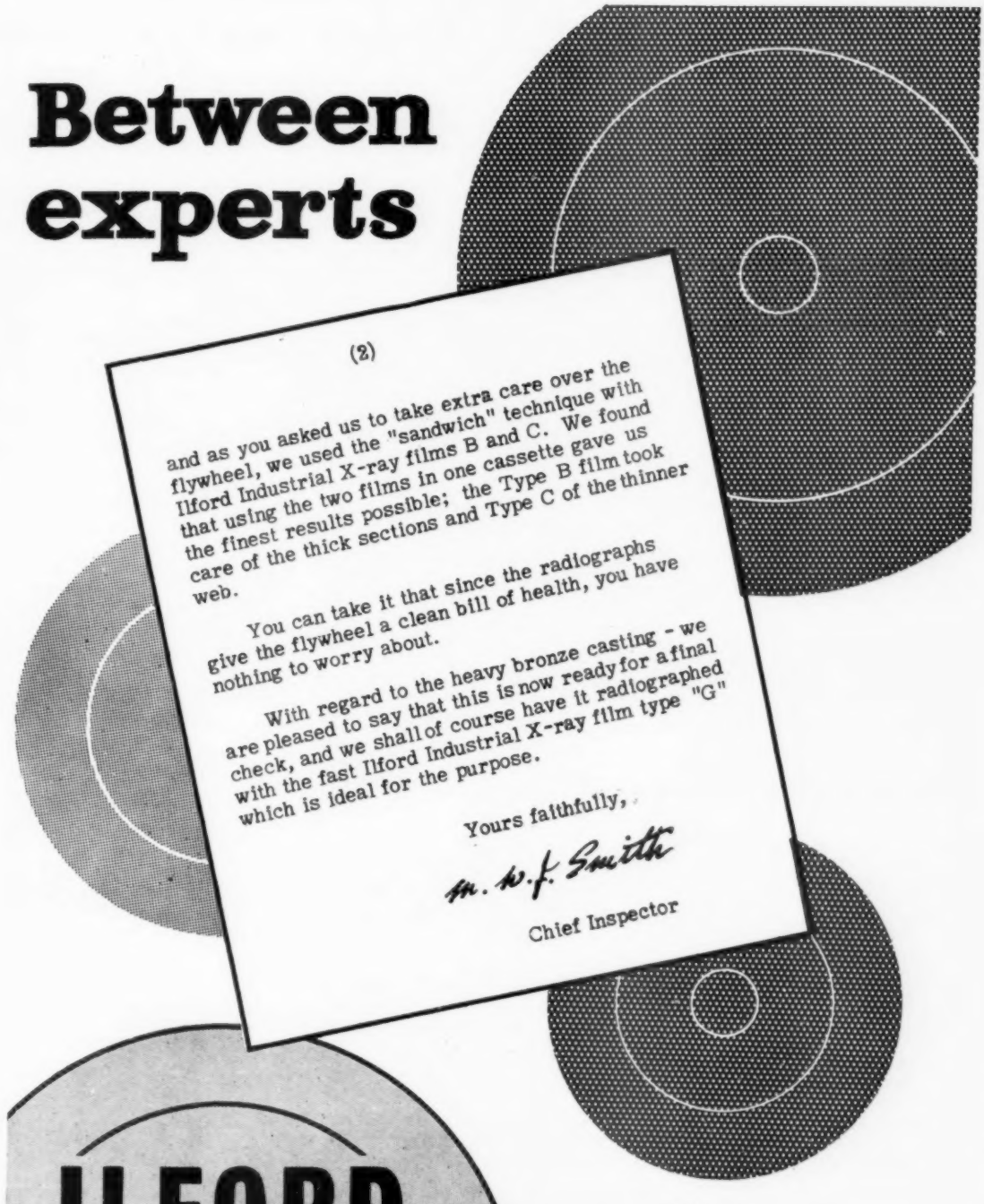
(2)
and as you asked us to take extra care over the flywheel, we used the "sandwich" technique with Ilford Industrial X-ray films B and C. We found that using the two films in one cassette gave us the finest results possible; the Type B film took care of the thick sections and Type C of the thinner web.
You can take it that since the radiographs give the flywheel a clean bill of health, you have nothing to worry about.
With regard to the heavy bronze casting - we are pleased to say that this is now ready for a final check, and we shall of course have it radiographed with the fast Ilford Industrial X-ray film type "G" which is ideal for the purpose.
Yours faithfully,
Chief Inspector

ILFORD

X-RAY FILMS

FOR INDUSTRIAL RADIOGRAPHY

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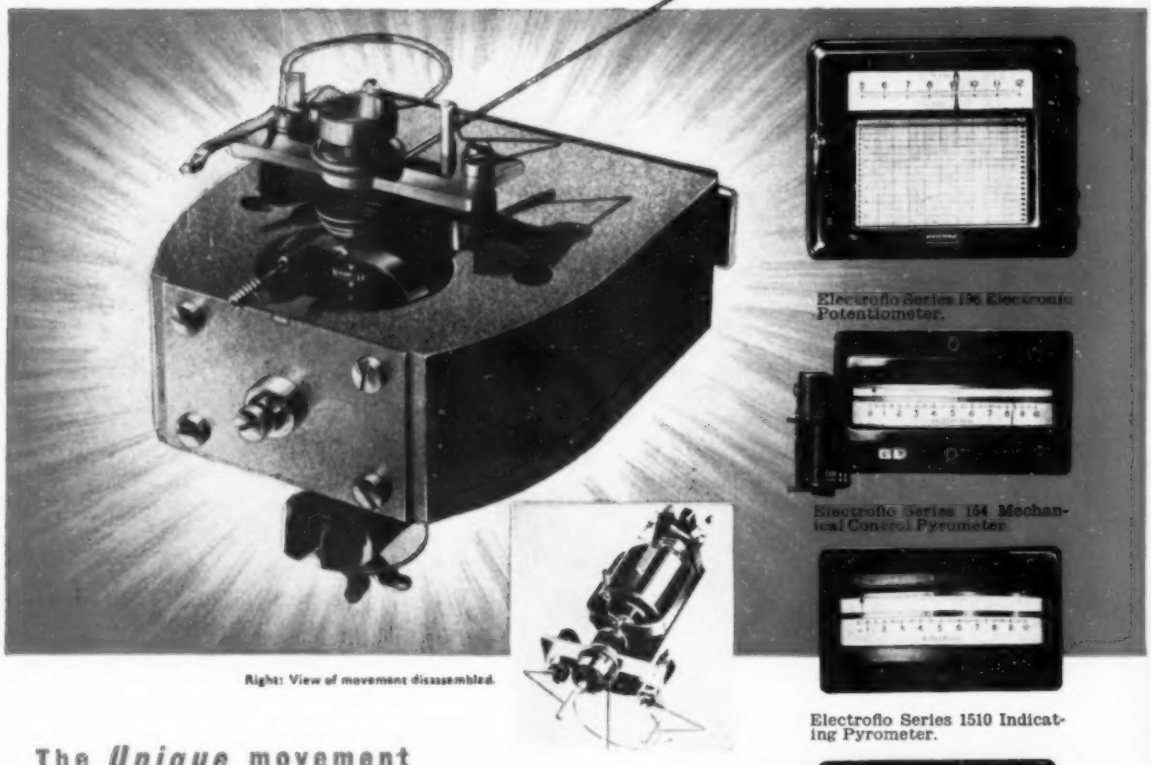
The Reference Standard for Precision and Reliability

ELECTROFLO TEMPERATURE MEASUREMENT AND CONTROL—



Right: View of movement disassembled.

Electroflo Series 136 Electronic Potentiometer.

Electroflo Series 154 Mechanical Control Pyrometer.

Electroflo Series 1510 Indicating Pyrometer.

Electroflo Series 1520 Electrical Resistance Thermometer.

Electroflo Model No. 15112, 12pt. Indicating Pyrometer.

The *Unique* movement

★ Patented magnetic system: concentric uniform field: negligible flux loss.

★ Moveable element weight 2.3 gms.: sprung sapphire mounting.

★ Large air gap – no stiction.

★ Roller mount eliminates errors of commonly employed core fixing means.

★ Automatic cold junction compensation.

★ Unequivocal lifetime guarantee of high performance —consistently maintained.

A 24-HOUR COMPLETE SERVICE IN ANY PART OF THE UNITED KINGDOM.

For particulars of full range of Indicators: Recorders and Controllers and Electroflo Electronic Potentiometers write for leaflet No. 170/S1.

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METERS COMPANY LIMITED

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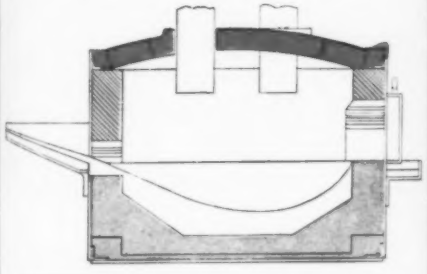
Factories: Abbey Road & Chase Estate, Park Royal and Maryport, Cumberland.
Telephone: Elgar 7641 8. *Grams & Cables:* Elflometa, London, Telex. Telex No. 2-3196.

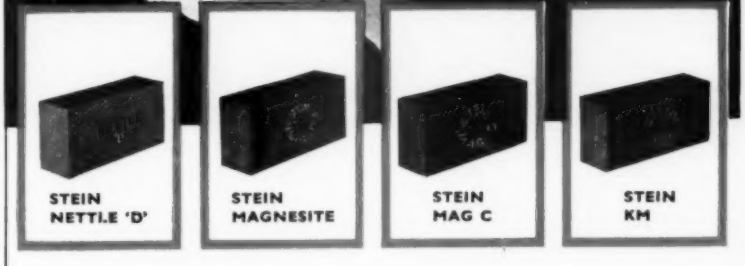
STEIN *Basic Refractories*

BASIC ELECTRIC STEEL FURNACE



STEIN MAGNESITE	Hearth up to slag line
STEIN MAG C	Side Walls. Jointing with steel plates is specially recommended
NETTLE 'D'	43% Alumina
MYRTLE	96% Silica Furnace Roof

Here is a combination of refractories designed to give long life, maximum output and minimum refractory cost.



in the Steel industry where quality counts

For over 70 years Stein Refractories have proved their dependability in service to the iron and steel industries. Constant research ensures continued leadership.

✻ *Our advisory service based on 70 years' experience in the iron and steel world can improve your furnace efficiency.*

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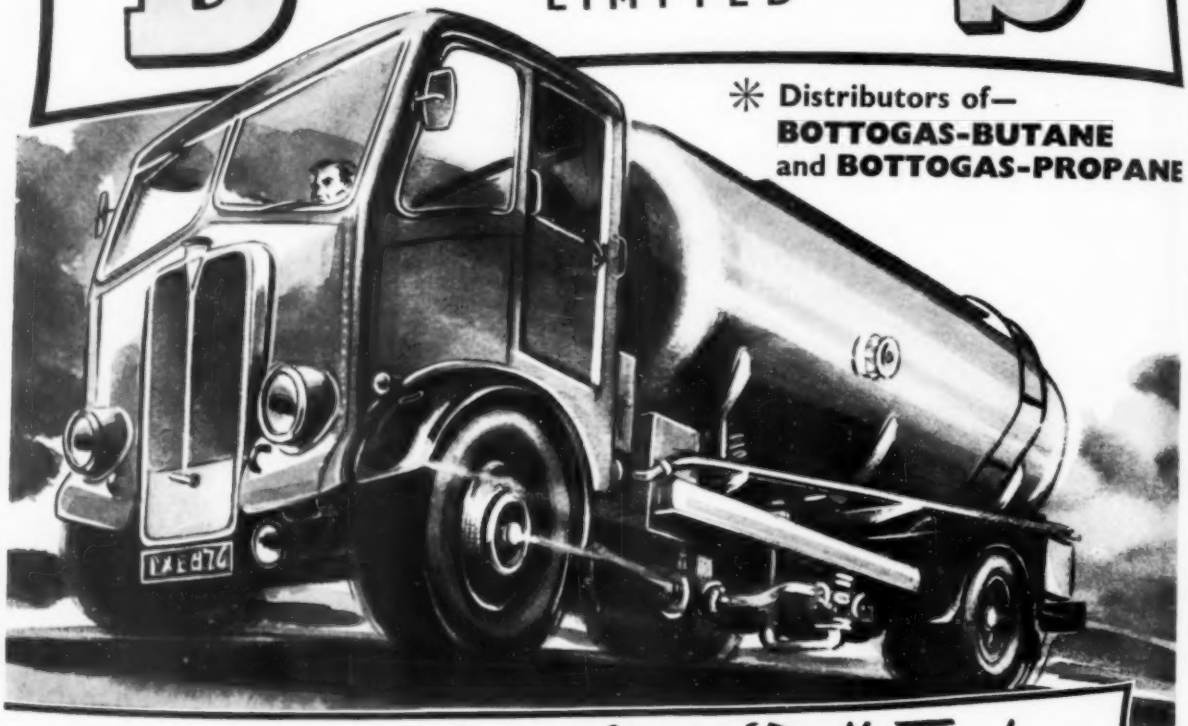

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'Barton' meter now manufactured by SUNVIC

The well-known 'Barton' meter is now being manufactured under licence in the U.K. by Sunvic Controls Limited. Using mechanically linked, liquid-filled bellows, the instrument provides rotation of a torque-tube corresponding to changes in applied differential pressure.
The torque arm can either be coupled to a transmitter to provide 3-15 p.s.i. output or can be mechanically linked to an indicating gauge or recorder.

ROBUST
Bodies of either stainless or cast steel, pressure-rated to 2,500 p.s.i.
Rupture-proof bellows of stainless steel.
Differential overload rating same as static pressure rating.
Available for operation in ambient temperatures of –25°F to 200°F.
Built-in adjustable pulsation dampener.

WIDE RANGE
Differential pressure ranges of 0-25 inches w.g. up to 0-400 inches w.g.

NO LIQUID SEALS
Stainless steel bellows allow direct contact with corrosive or volatile liquids.

SELF-VENTING — SELF-DRAINING
All condensate returns to flow line.

Full technical information available from
Sunvic Controls Limited, P.O. Box 1, Harlow, Essex, Tel: Harlow 24231/5

SUNVIC
An A.E.I. Company

Not only instruments but complete instrumentation
for integrated monitoring, control and data handling of nuclear reactors and industrial processes

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A HARD AND CORROSION RESISTANT PLATE

APPROVED UNDER D.T.D. 900/4505

A skew gear, Kanigen plated all over for wear resistance

KANIGEN: is a nickel-phosphorus plate deposited by chemical reduction. It gives complete, uniform coverage to parts of complicated shape and the thickness can be controlled to fine limits.

PROPERTIES:

Composition	92% Nickel 8% Phosphorus
Melting Point	890°C.
Electrical Resistivity	60 microohm cm.
Hardness	500 – 1,000 V.P.N. according to heat treatment.
Uniformity	within ± 10%

Kanigen can be applied to all steels, including stainless steel, and to aluminium, copper, brass and cast iron. Kanigen is a registered trade mark of Albright & Wilson Ltd.

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Considerable capacity is available for jobbing plating

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CONTINUOUS
TUBE RE-HEATING FURNACE

Oil fired Furnace installed at the Clydesdale Works of Stewarts & Lloyds Ltd., for re-heating 9⅞ in. dia. and 46 ft. long from 700°C. to 950°C. prior to sizing mill. The furnace is fully instrumented, controlled in 3 zones and complete with charging and discharging equipment.

We specialise in the design and construction of :—

Open Hearth Furnaces
Soaking Pits
Furnaces for Aluminium Melting, Coil Annealing and Slab Re-heating
Stress Relieving Furnaces
Forge and Heat Treatment Furnaces
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also at TELEGRAPH BUILDINGS HIGH STREET SHEFFIELD

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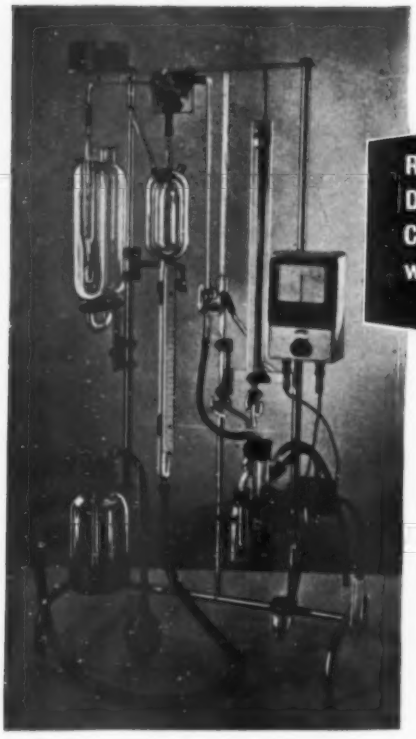
Genuine *Ströhlein* apparatus

for volumetric determination of carbon and sulphur in iron and steel



Rapid Simultaneous Determination of Carbon and Sulphur with potentiometric end point.

This apparatus determines simultaneously the carbon and sulphur content of a sample in four minutes to within an accuracy of ± 0·001 p.c.S and 0·005 p.c.C. Results are reliable even in the presence of alloys.

The sample is placed in a furnace and heated to 1,200° C. in a stream of oxygen. The resulting gas contains the elements to be determined as CO_2, SO_2 and SO_3 and is first passed through a solution of H_2O_2. Here the entire sulphur is retained as H_2SO_4 and its amount measured by titration. The remaining gases pass to an absorption system containing KOH where the carbon content is determined by the volume of CO_2 absorbed.

End Point Indicator: A galvanometer with sensitivity control is used in conjunction with a mercury reference electrode. As the H_2O_2 solution used already contains a little SO_4 initial titration is required to bring the galvanometer back to zero.

With practice, C and S determinations may be carried out simultaneously, 10 samples in twenty minutes being quite a reasonable result.

Volumetric Determination of Carbon

This improved new model while following the well-known procedure of previous models has been designed to save considerable time and work. Using two absorption vessels, testing time is reduced considerably, while the burette and the cocks are conveniently arranged at the bottom of the apparatus so that the operator can sit while working. This is possible because the barrier liquid is moved by compressed air supplied from a membrane pump, obviating the necessity for the operator to raise and lower the levelling bottle continuously. Other improvements incorporated in this new apparatus include Automatic Burette zero adjustment; Gas transfer speeded by use of compressed air.

This Carbon Determination Equipment is suitable for samples containing between 0·05 p.c. and 4·5 p.c. of Carbon. Its rapidity of operation enables a complete determination to be made in less than 5 minutes. In many works laboratories more than 100 analyses per day are regularly being carried out with this equipment.

Interchangeable burettes are available covering the ranges: 0—0·25 p.c.; 0—0·5 p.c.; 0—1·5 p.c.; 0—4·5 p.c.

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Roofing Quality Super Purity (99.99%) Aluminium

Architect: T. C. Hartley A.R.I.B.A., Borough Architect. Roofing Contractors: Richard Pickersgill & Sons Ltd.

Roofing Quality Super Purity has been introduced to provide the qualities of the well-tried Flashing Quality, together with the added benefits of greater strength and stiffness, so important in large area roof weatherings. It is shown here used to cover the new Roseworth Library at Stockton-on-Tees.

Roofing Quality Super Purity is worked by traditional hard metal techniques. It possesses excellent resistance to atmospheric attack, while its light weight eases the tasks of handling and fixing. Moreover, it is considerably cheaper than any other roofing metal of comparable life.

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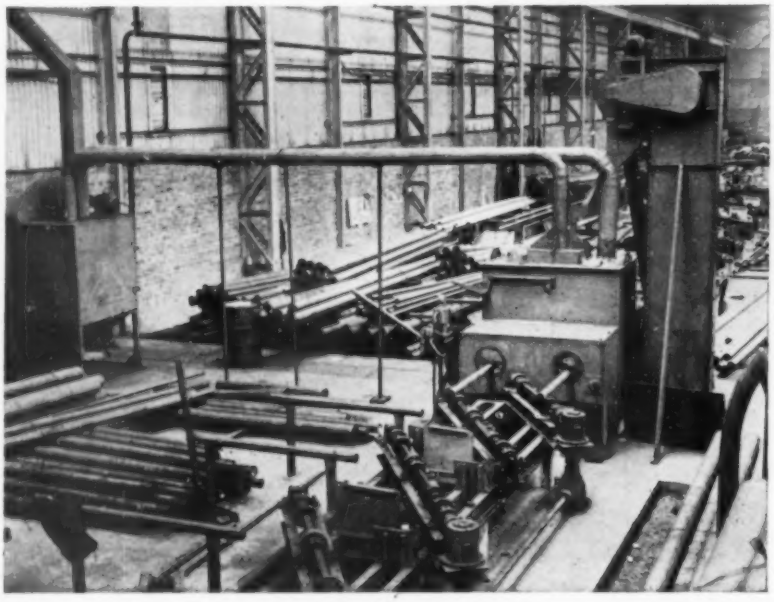

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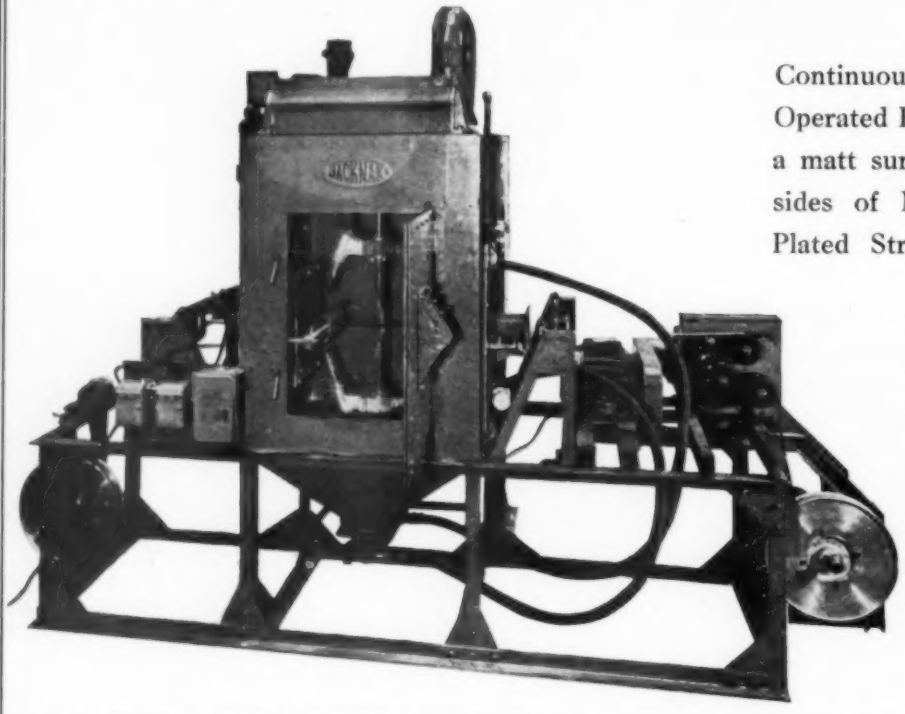
Jackman Special Purpose Shot Blast Equipment

Airless Plant with a Single Impellor cleaning two tubes simultaneously. The tubes are rotated and traversed by rollers. The plant is suitable for tubes from 2 in. dia. to 10 in. dia.

Rate of cleaning:—
20 sq. ft. per minute



Continuously Acting Air Operated Plant for producing a matt surface on both sides of Nickel or Nickel Plated Strip

The equipment is complete with Coiling Gear

We shall be pleased to quote for Plant to meet your needs

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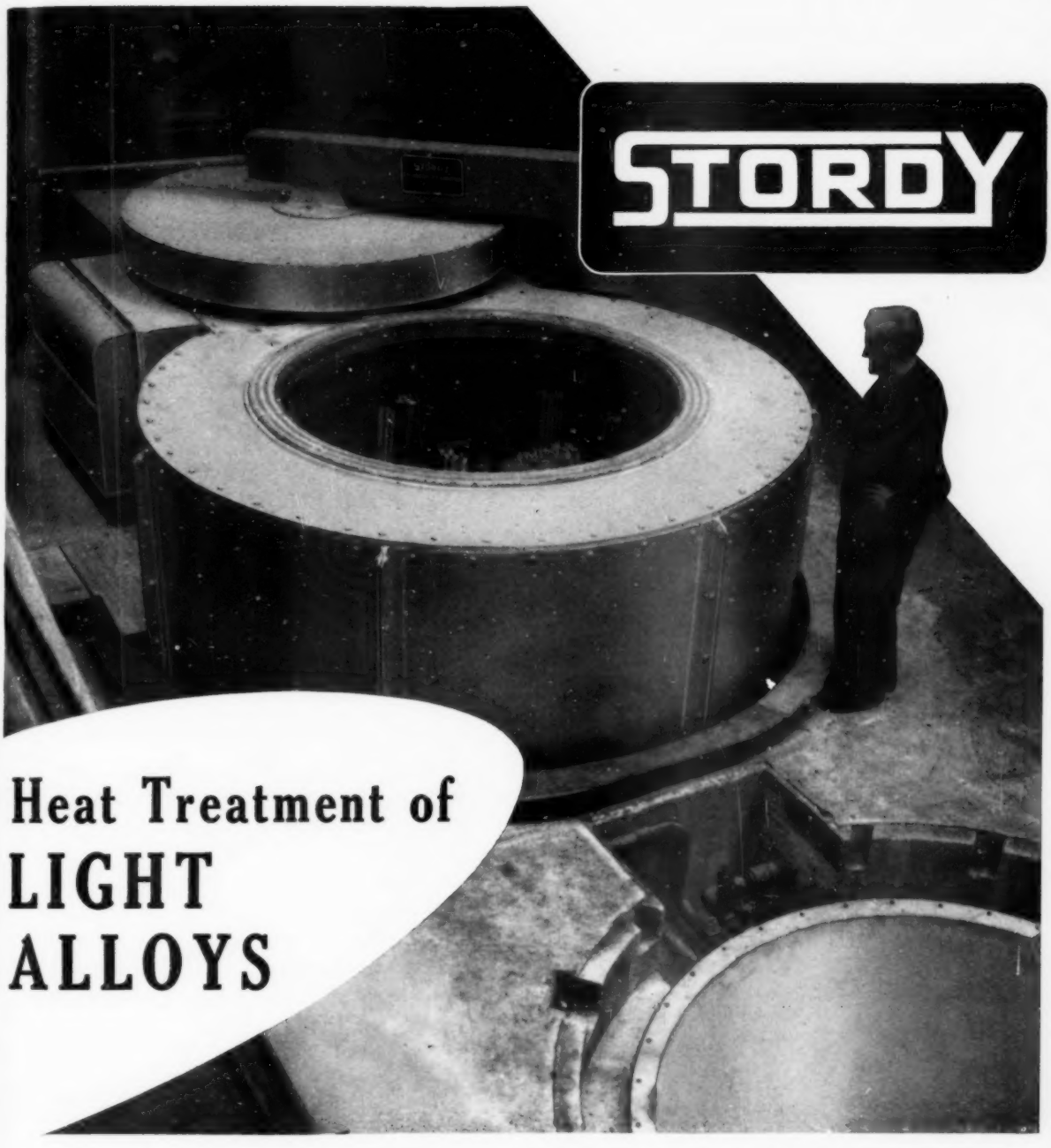

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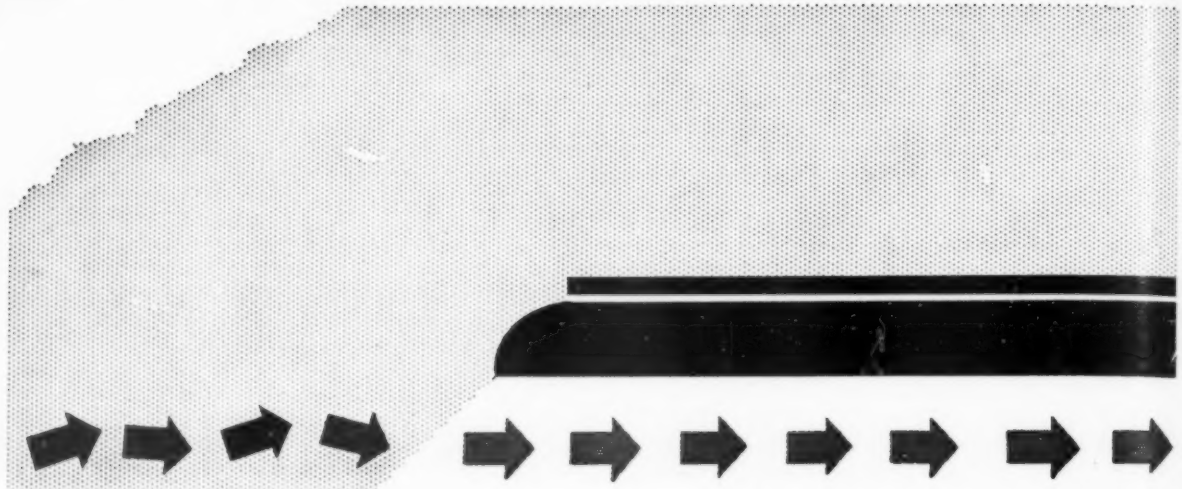
Greater efficiency, more precise control, higher output with considerably less maintenance and running costs—these are the features that place these STORDY Electric Furnaces ahead for light alloy treatment. Unit construction of heater battery allows ready derating adjustment for precipitation treatment and annealing—with same precise temperature control. In addition, the heater battery is remote from the furnace chamber and therefore easily accessible for inspection without dismantling. The large capacity centrifugal fan gives greater air circulation.

The furnace illustrated is for the heat treatment of extruded sections—work dimensions 5 ft. diameter by 8 ft. deep.

STORDY ENGINEERING LIMITED
CUMBRIA HOUSE · GOLDTHORN HILL · WOLVERHAMPTON



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Better Production

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The *right* lighting has a significant effect on the speed and accuracy of production. When its strength, position and type is suitable for each job the craftsman can give full play to his skill, and the works engineer can do full justice to his shop.

Good lighting is only one of the many ways in which electricity is playing a vital part in the drive for higher productivity.

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Ask your ELECTRICITY BOARD for advice and information, or get in touch with E.D.A. They can lend you, without charge, films about the uses of electricity in industry. E.D.A. are also publishing a series of books on Electricity and Productivity. Titles now available are: Lighting in Industry, Electric Resistance Heating, Electric Motors and Controls, Higher Production, Materials Handling, and the latest addition to the series, Induction and Dielectric Heating. Price 8/6, or 9/- post free.

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1. Aluminium Bale Out Furnace
2. Cyanide and Preheating Pot Furnace
3. Gas Fired Semi-Muffle Furnace
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(Subsidiary Company of Gibbons Bros. Limited, Dudley)

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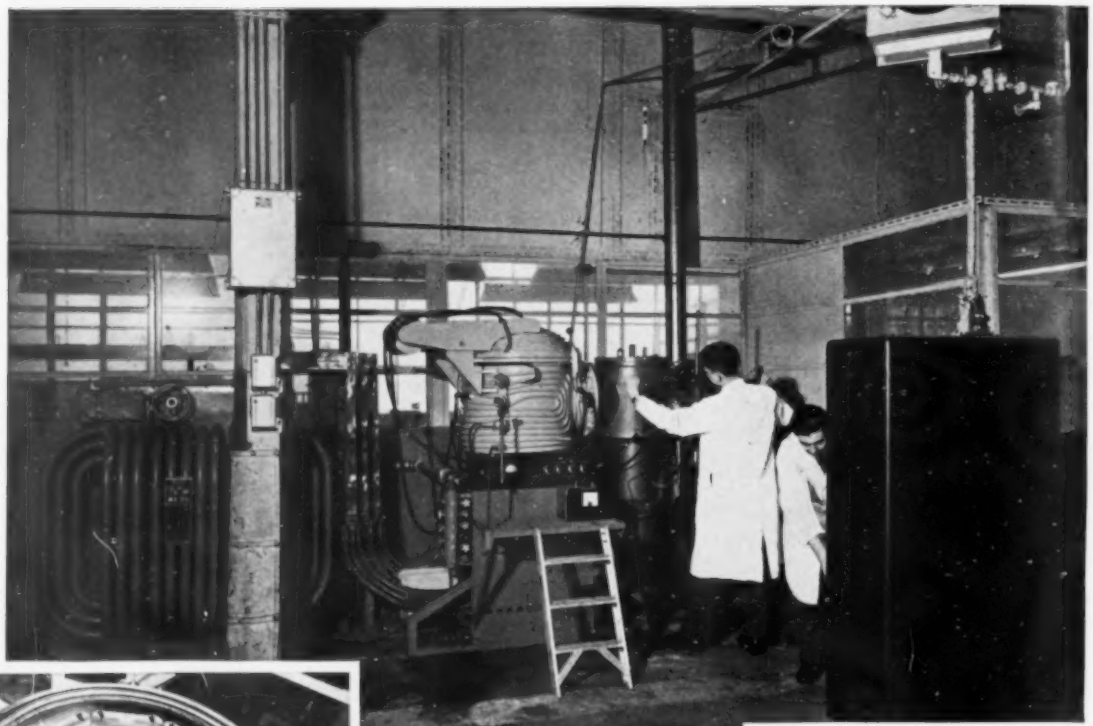
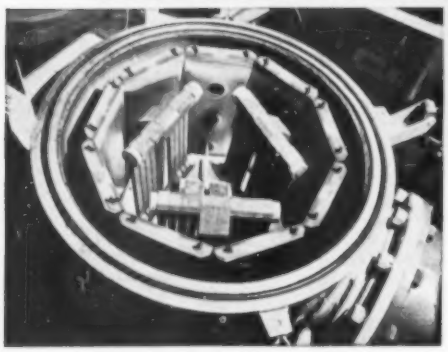
B.S.A. use a G.E.C. High Temperature Vacuum Furnace...



G.E.C. High Temperature Vacuum Furnace installed in the B.S.A. Group Research Powder Metallurgy Laboratory at Small Heath, Birmingham.



The furnace element assembly and side radiation screens.

for sintering materials for use at high temperatures

G.E.C. vacuum furnaces meet the need for high temperatures for such applications as sintering and degassing, brazing with nickel chromium alloys, heat treating titanium, tantalum and zirconium.

They provide an operating vacuum between 10^{-4} and 10^{-5} mm. mercury. Temperatures up to 2000°C. have been achieved.

Write for further details.

for efficient process heating use

G.E.C.

FURNACES • HIGH FREQUENCY • INFRA-RED

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THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

Three pointers to your problem?

We know just how difficult it is to say, in a particular case, that a change of refractories is responsible for improved performance. But when a similar change produces, again and again, similar results, there is likely to be a relationship between the two. We suggest, therefore, that, if you use furnaces, ovens, kilns or boilers, it could pay you to consult Morgans about the refractories.

note the common factor... TRI-MOR*

MORGAN Refractories

*TRI-MOR *is the generic name for the castable and mouldable refractories manufactured by Morgan Refractories Ltd.*

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CASTABLES AND MOULDABLES, TUBES AND HOLLOW WARE

1

Reheat Furnace

The burner quarls of a large reheat furnace in a Midlands steelworks fired with a mixture of coke oven and B.F. gas were rebuilt in TRI-MOR High Temperature Mouldable over three years ago and are still in good condition. This is *nine* times the life of previous refractories.

2

Burner Quarls

During the basin trials of a new cargo liner the burner quarls (of a competitive refractory) broke up. They were replaced by new quarls by another manufacturer; these melted and disintegrated during the second trial. Finally, TRI-MOR High Temperature Mouldable quarls were installed. These were described by the boiler-makers' engineer as being 'Absolutely perfect' after the trials.

3

Arc-furnace Roof

A trial section of TRI-MOR High Temperature Mouldable placed between the electrodes in a steel melting arc-furnace roof was examined, after 113 heats. It was found to be standing proud of the lining of silica brick, which showed considerable wear. The silica lining normally lasts for 120 heats. If the present relative rates of erosion continue it is estimated that a TRI-MOR lining will outlast two silica linings and it is, therefore, proposed to line the whole roof with TRI-MOR.

For further information please write to: MORGAN REFRACTORIES LTD., NESTON, WIRRAL, CHESHIRE. TELEPHONE: NESTON 1406
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TGA HN4

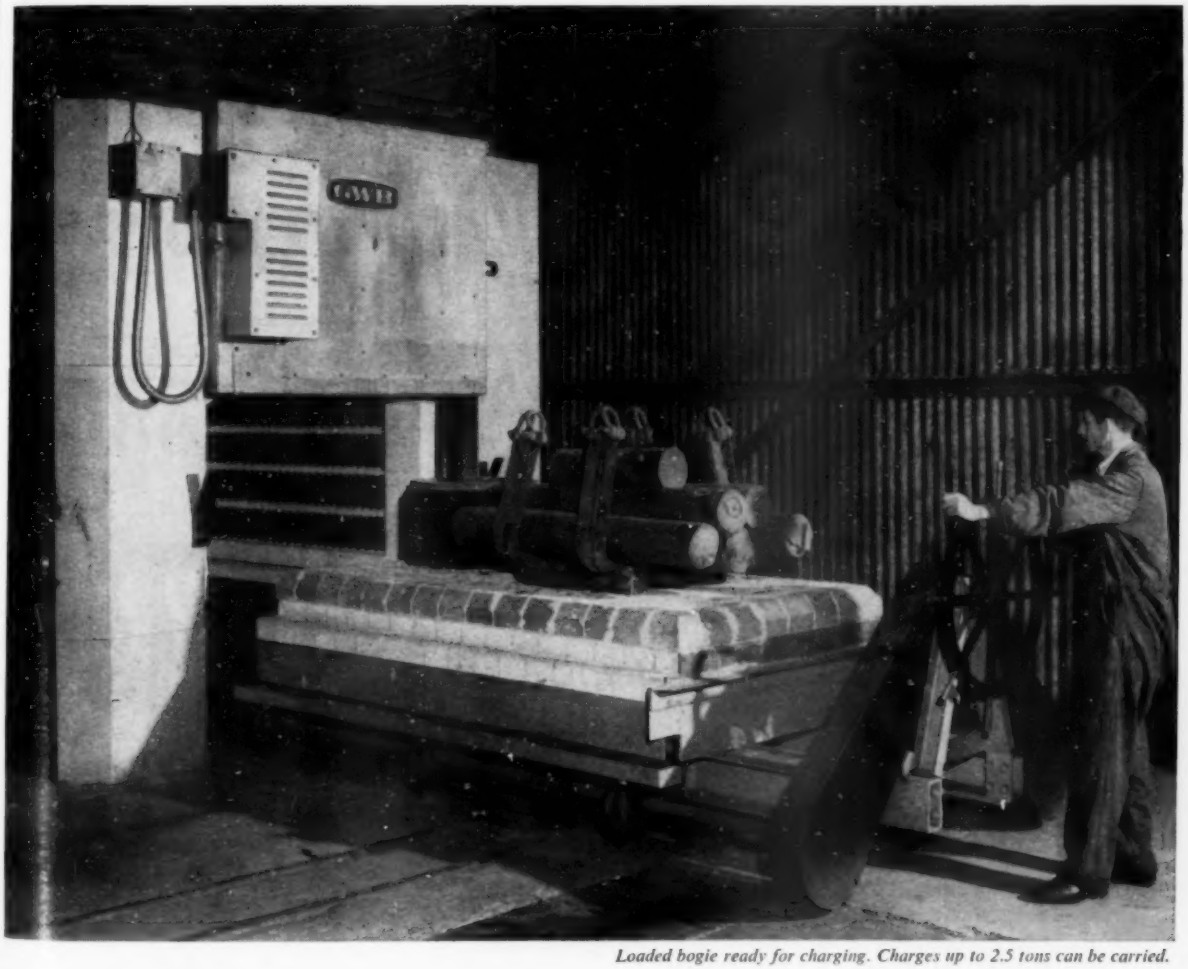
G.W.B. BOGIE HEARTH FURNACE HEAT-TREATS MARINE ENGINE FORGINGS

100% reliability is an essential condition with all equipment used in ship building. This is especially the case with the main engines and so the heat-treatment carried out on the various component parts must be accurate and uniform. This is why the well known forging firm of T. S. Forster & Sons Ltd., who, among other items associated with ship building, make forgings for marine diesel engines, chose a G.W.B. electrically heated Bogie Hearth Furnace for hardening many of these parts, including piston heads and connecting rods. A cleanliness of operation, not normally associated with a forging works is obtained together with close automatic temperature control, thermal uniformity and trouble-free operation.

FURNACE CHARACTERISTICS

- **Effective dimensions: 7'0" long x 4'0" wide x 2'6" high**
- **Rating: 120 kWs in one zone**
- **Temperature: 1,050°C maximum**

Let G.W.B. help you with YOUR furnace problems. Over twenty-five years of experience in electric furnace design are at your disposal.



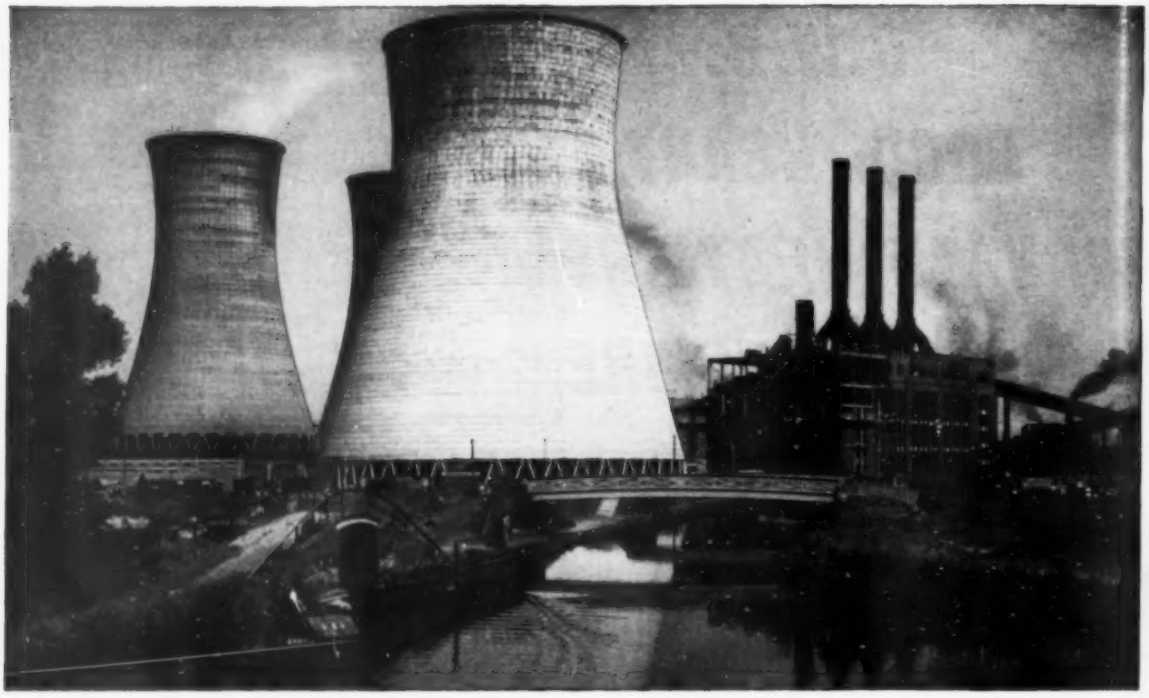
Loaded bogie ready for charging. Charges up to 2.5 tons can be carried.

GWB G.W.B. FURNACES LTD., P.O. BOX 4, DIBDALE WORKS, DUDLEY, WORCS.

TELEPHONE: DUDLEY 4284/5/6/7

Proprietors: Gibbons Bros. Ltd., and Wild-Barfield Electric Furnaces Ltd.

GWB14



Staffordshire Landscapes

The perfect marriage of old and new takes place as the traditional canal boat brings fuel to today's power generators.

Change is not always ruthless, nor synonymous with replacement in South Staffordshire, where, when benefits accrue, the new teams happily with the old, taking the best of modern methods and ancient skills and blending them into a realistic approach to the problems of an atom age.

Progress in Staffordshire, bringing almost every major improvement in the technique of iron-founding since 1700, is apparent in the landscape of the County as well as in its products.

For almost a century and a half Pig Iron has been manufactured at Darlaston Iron Works. Today, the most modern methods of metallurgical control of raw materials and the finished product, enables them to supply Pig Iron of consistent uniformity to the most exacting specification.

Bradley & Foster
LIMITED

FOR QUALITY CONTROLLED
REFINED PIG IRON

DARLASTON · STAFFORDSHIRE

A member of the Staveley Coal & Iron Co., Ltd., Group.

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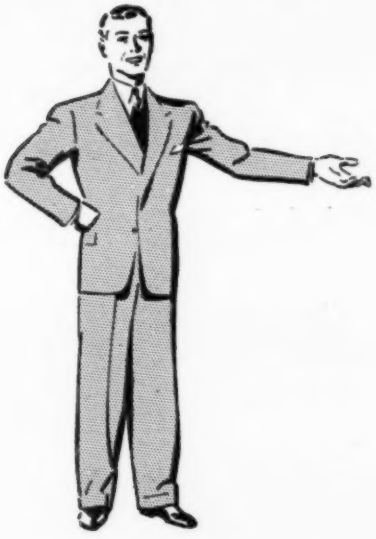

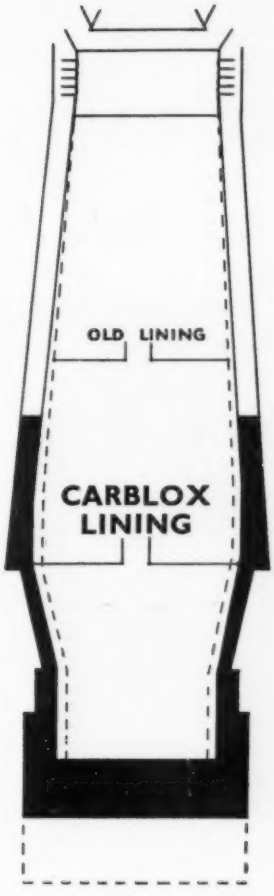

To increase productivity have a thinner lining in the same furnace shell by using CARBLOX

For the
WELL WALL, BOSH AND HEARTH

CARBLOX is manufactured by CARBLOX LTD., a company in which THE MORGAN CRUCIBLE COMPANY LTD. and THOMAS MARSHALL & COMPANY (LOXLEY) LTD., are jointly associated.

More iron can be made in an existing blast furnace if a thinner lining is used to give greater furnace capacity. This can be achieved by using Carblox which has a much greater resistance to the attack of iron and slag than normal firebrick. The after contraction is low and its high thermal conductivity increases cooling efficiency. Ordinary firebrick fails at 2910°F under a load of only 50lb/sq. in. yet CARBLOX shows no deformation under a load of 2 tons/sq. in. CARBLOX is 2-3 times as resistant to abrasion and its mean cold crushing strength is about four times that of normal firebrick. Burden, molten slag and iron do not stick to it. CARBLOX must be used under reducing conditions.

Enquiries to :

CARBLOX LTD., NORTHFIELDS, WANDSWORTH PARK, LONDON, S.W.18. VANdyke 2366

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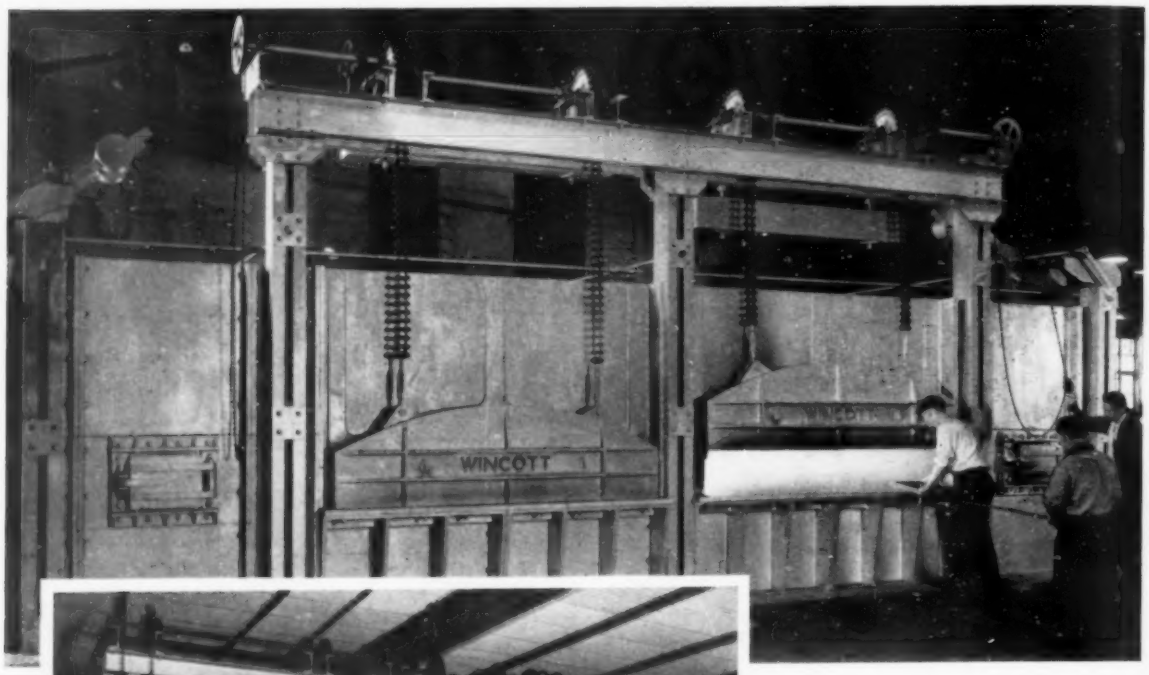
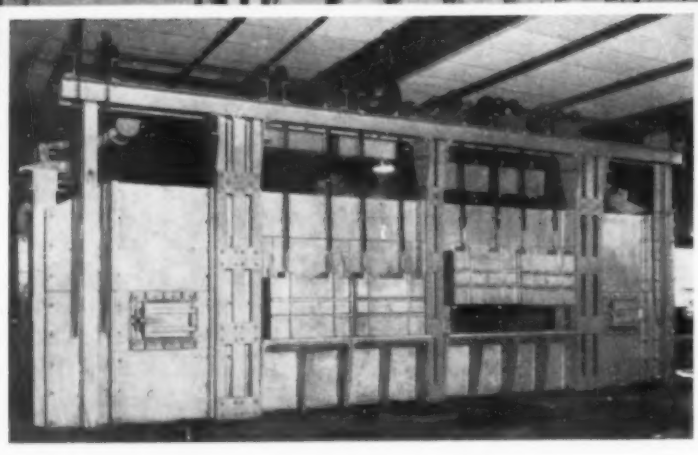
THE LATEST IN *Sheet Furnaces*
fired by AUTOMATIC COAL STOKERS





Above is a twin furnace with hearths 8′ 0″ wide by 9′ 0″ long, each fitted with a single door.

To the left is a twin furnace with hearths 6′ 0″ wide by 8′ 0″ long, each fitted with double doors.

Photographs by courtesy of Messrs. Darwins Ltd.

WINCOTT FURNACES

G.P. WINCOTT LIMITED SHEFFIELD, ENGLAND

Telegrams: WINCOTT, SHEFFIELD. *Telephone: 20211/2*

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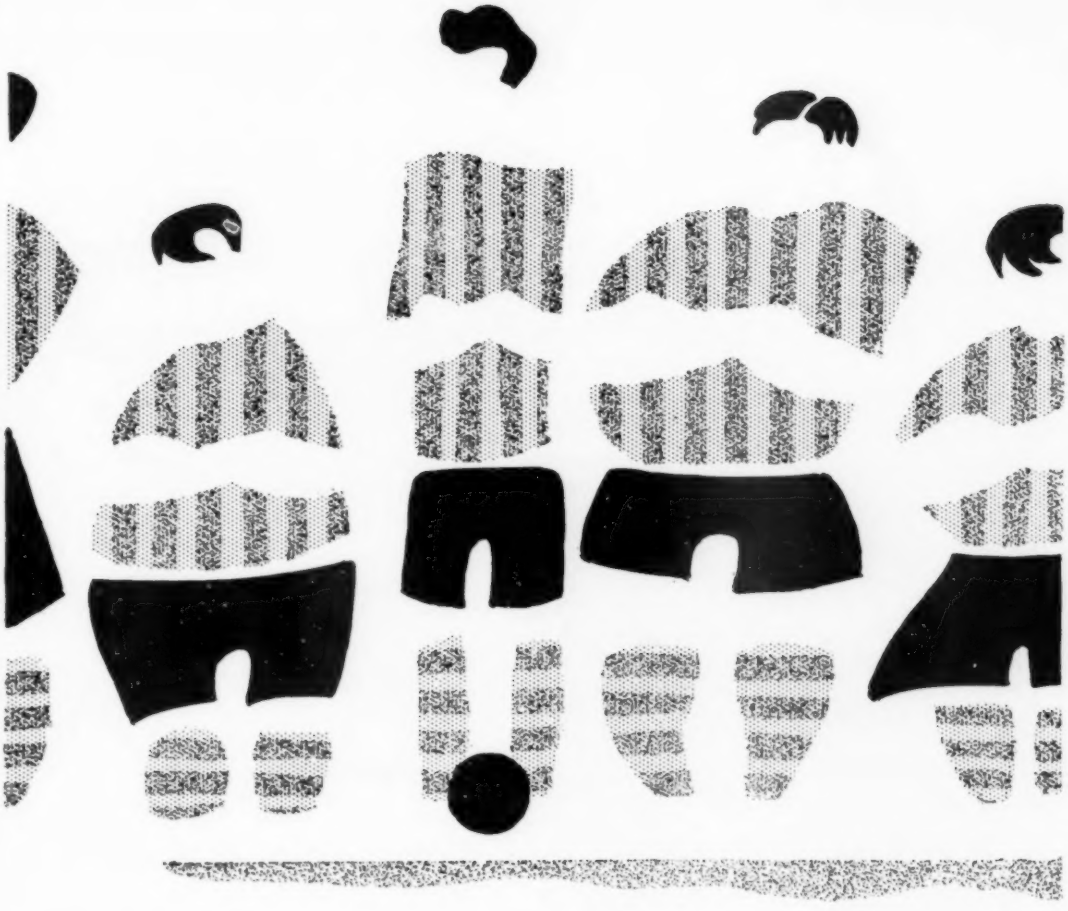

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Weight : 17¾ tons.
Dimensions :
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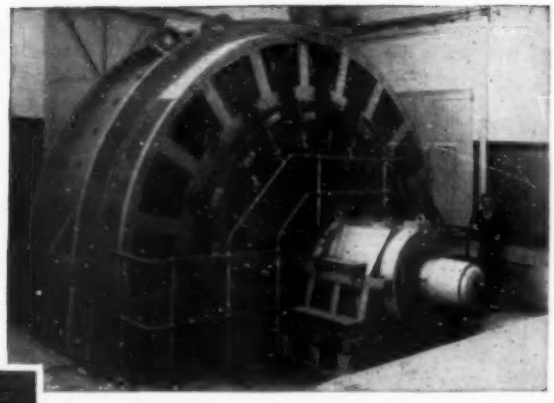
In association with Armstrong Whitworth (Metal Industries) Ltd., Close Works, Gateshead, 8, Co. Durham



Reversing D.C. Motor, peak torque capacity 200 metre-tons, for driving stainless steel strip mill. Supplied to the order of Firth-Vickers Stainless Steels Ltd.

A mercury-arc rectifier equipment with total capacity of 21,000 kW; installed at the Abbey Works of the Steel Company of Wales Ltd., for an 80-inch hot-strip finishing mill drive.

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of everything

Electrical for

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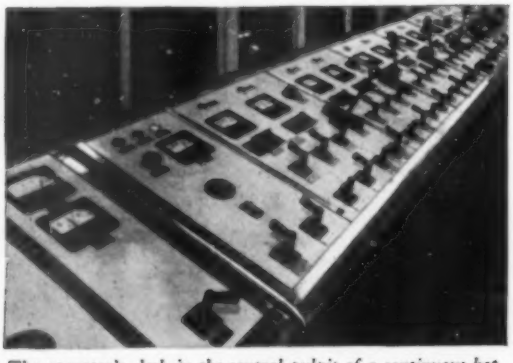
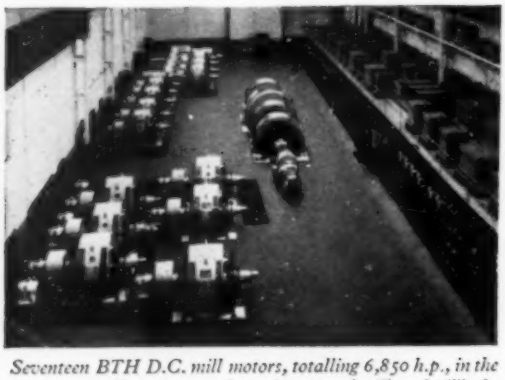


The operator's desk in the control pulpit of a continuous hot rolling mill.



Seventeen BTH D.C. mill motors, totalling 6,850 h.p., in the motor room of a two-strand continuous rod mill at the Works of Guest, Keen & Nettlefolds (South Wales) Ltd.

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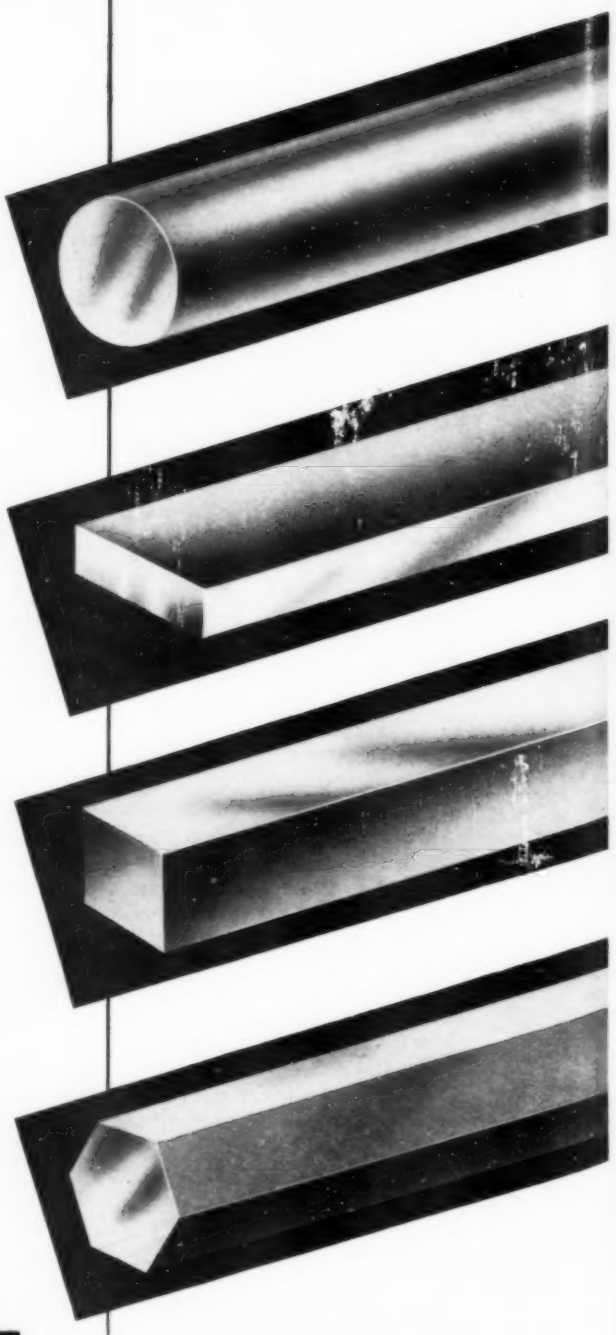

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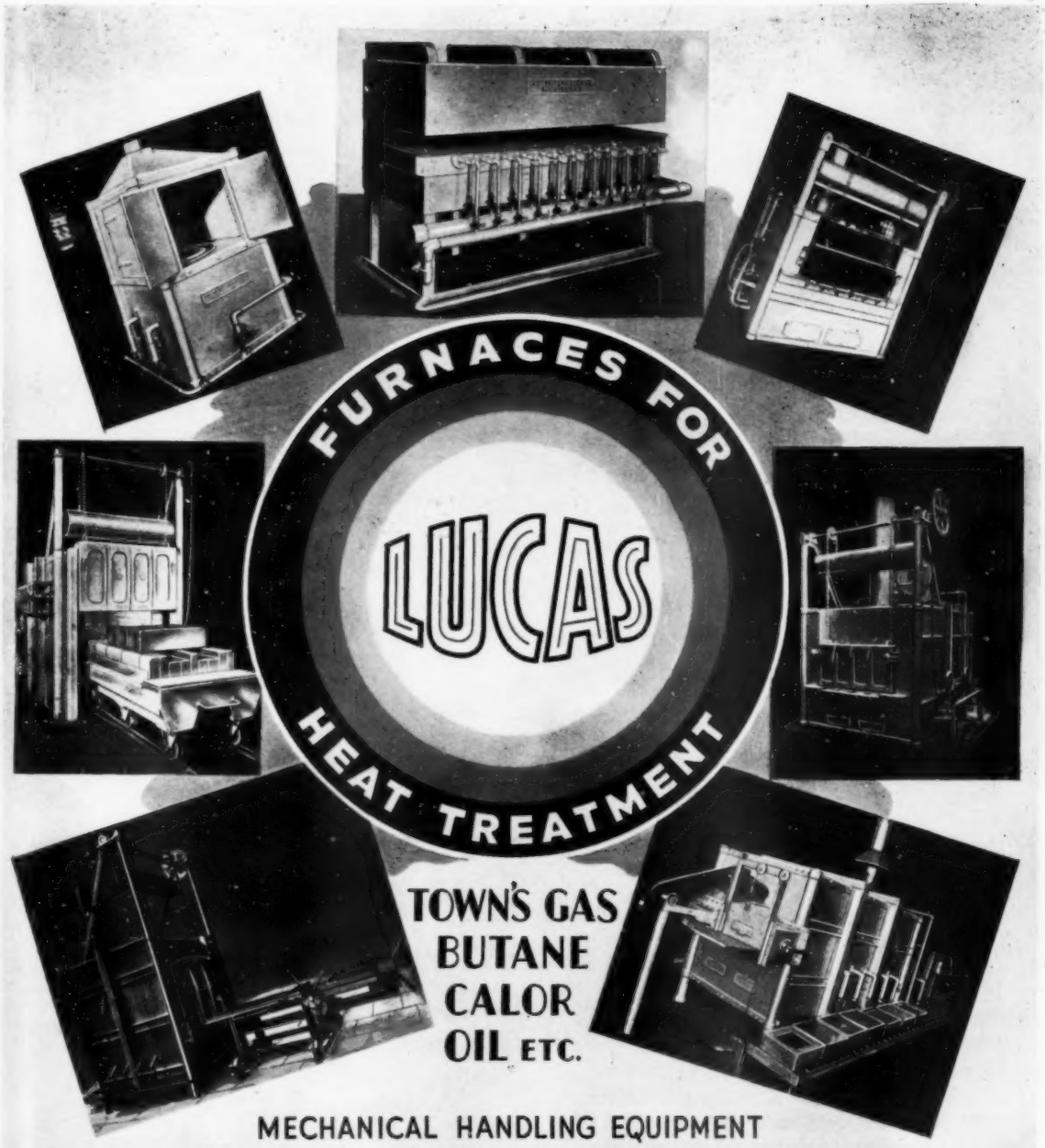

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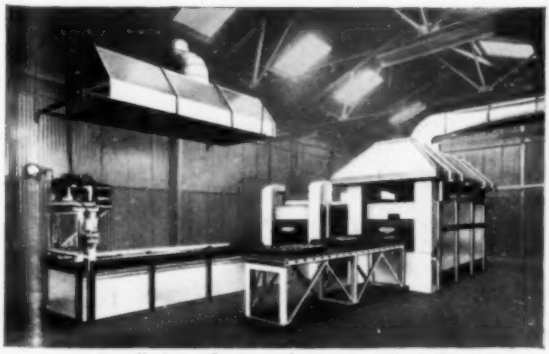

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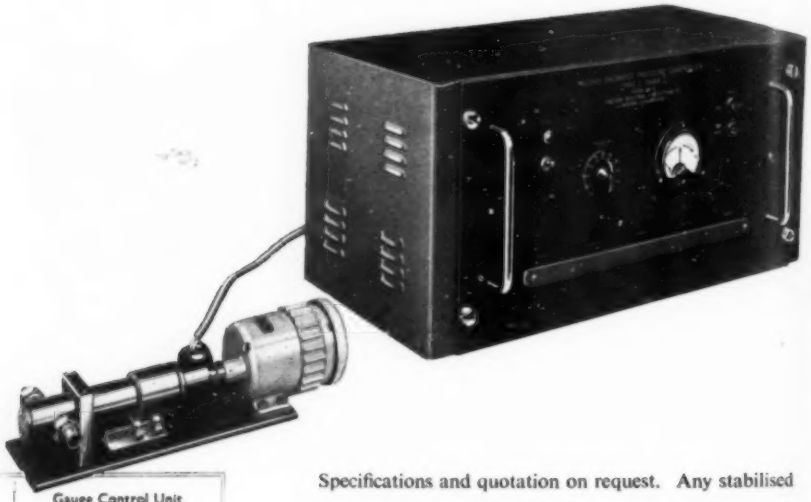
SERVO CONTROLLED NEEDLE TYPE LEAK VALVE



Pressure Range mm. Hg.	Type of Gauge Head	Gauge Control Unit
10^{-8} to 10^{-2}	G.I.	G.I, G.T.I, and P.O.A.C.E. All Types.
10^{-3} to 1	G.P.	G.P.I, etc.
10^{-3} to 100	G.A.	G.A, All marks
100 to Atmospheric	Pressure Transducer	Under development

Specifications and quotation on request. Any stabilised Gauge Control from which a 1-volt output can be obtained is suitable for use with the controller.

The servo system may also be operated by the current of an electrical discharge such as is used in cathodic sputtering or ionic cleaning.

The VIA-VAC Needle Type Leak Valve is fitted with a 2-phase motor energised from an amplifier controller incorporating proportional and derivative control. Stable operation and high resetting accuracy can be obtained at any pressure. Throughput range 5×10^{-2} to 5,000 lusec (5×10^{-5} to 5 litre torr/sec.) when supplied with gas at atmospheric pressure. A special version giving up to ten times the standard throughput can be made to order. Valve and motor are mounted on a common baseplate (11 × 4 in. × 4 in., weight 8 lb.) the controller on a standard 19 in. × 10½ in. panel (weight approx. 30 lb.). A suitable case (21½ × 10½ in. × 10½ in., weight 13 lb.) is available.

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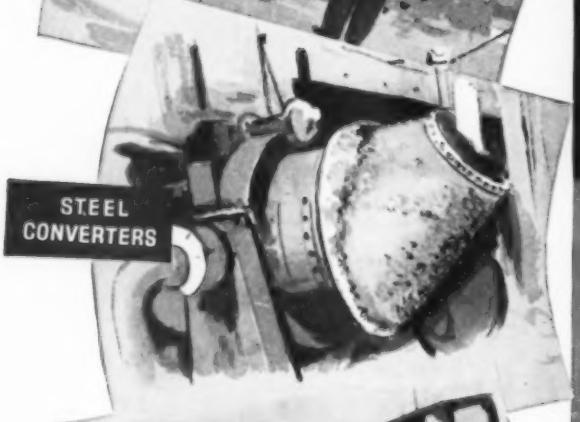

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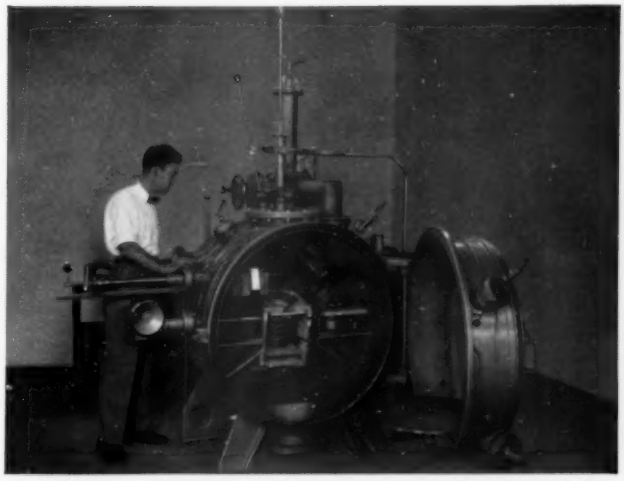

Model 2555 Vacuum Induction Furnace with melting capacity of 50 pounds of steel. Other standard furnaces have capacities of 12 to 3,000 pounds.

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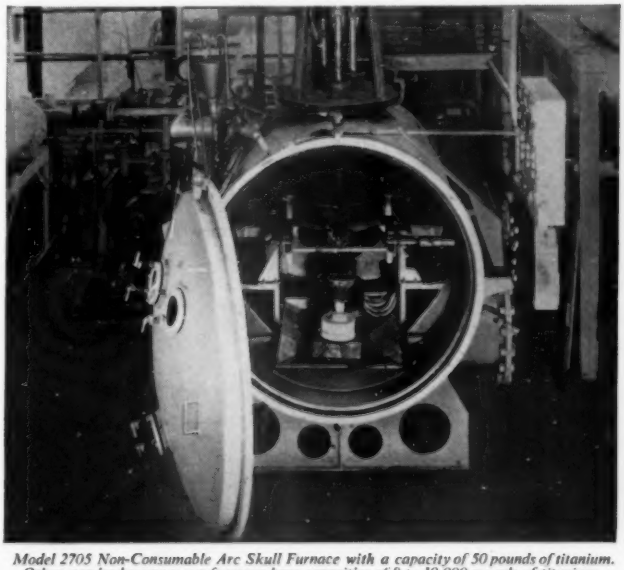

Model 2705 Non-Consumable Arc Skull Furnace with a capacity of 50 pounds of titanium. Other standard vacuum arc furnaces have capacities of 8 to 10,000 pounds of titanium.

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- **Vacuum Fusion Gas Analyser**
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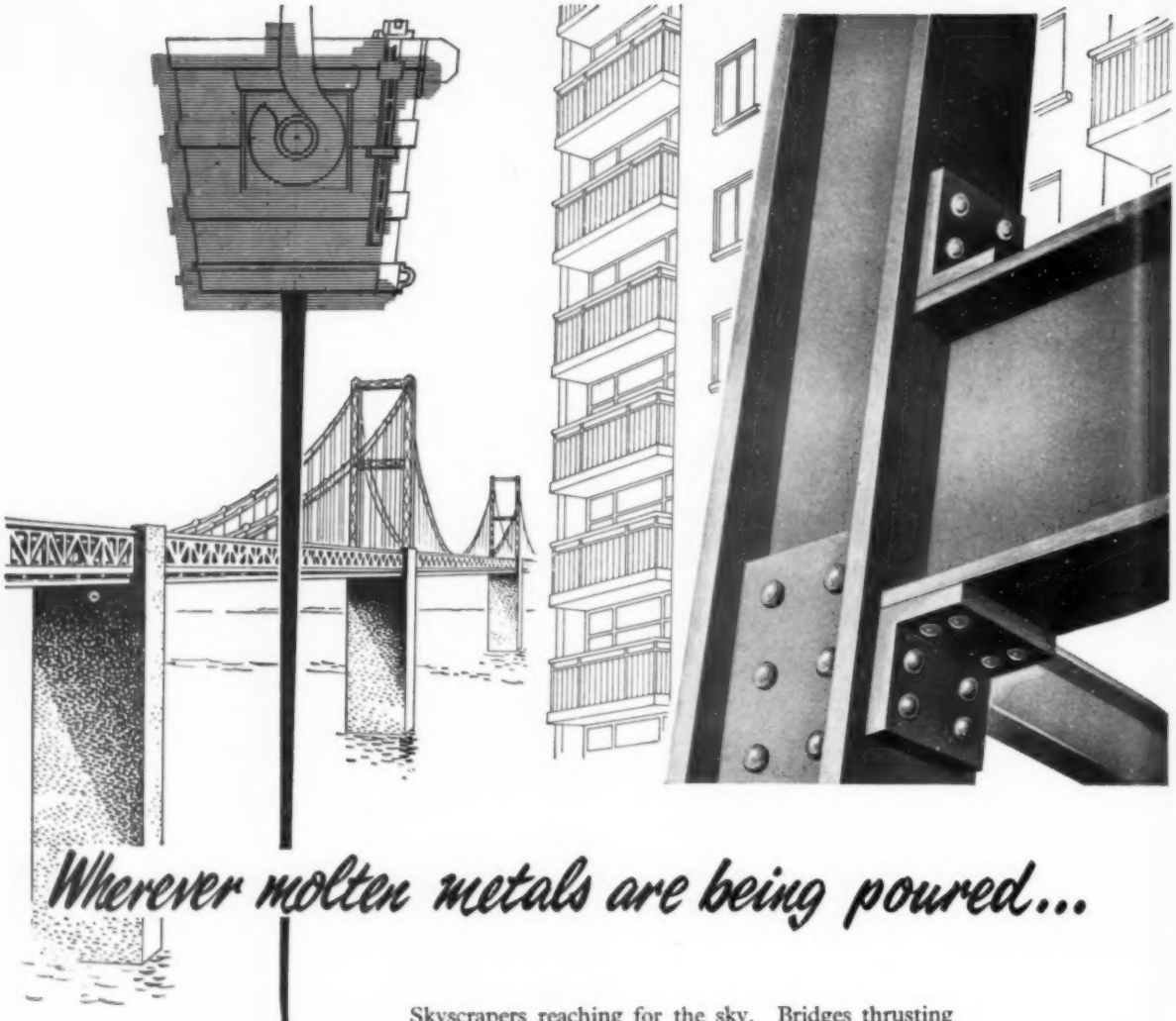

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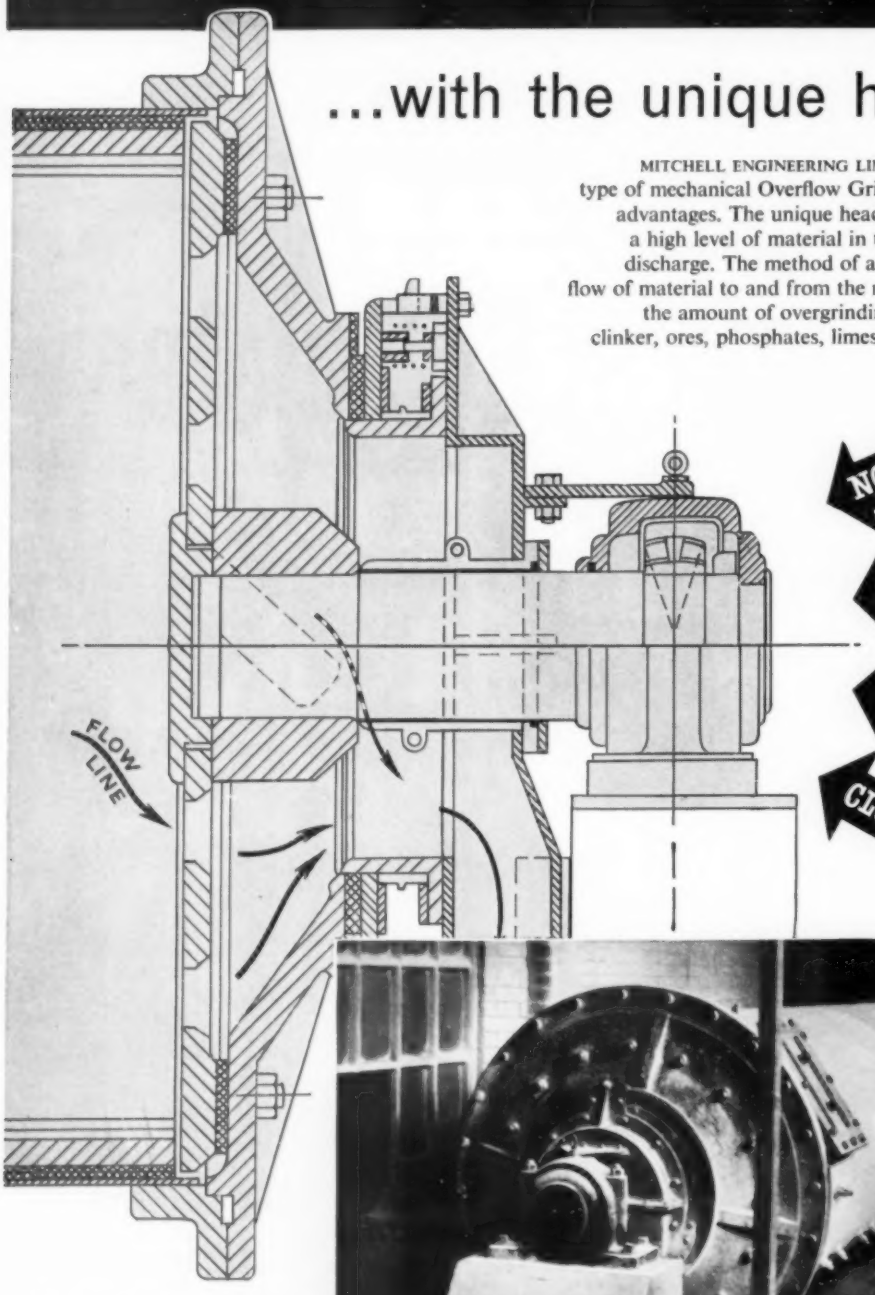

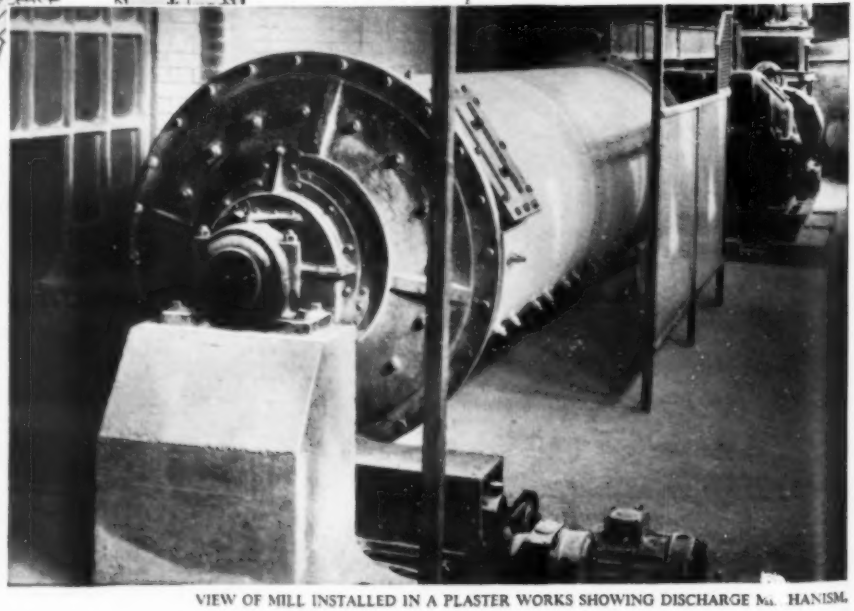

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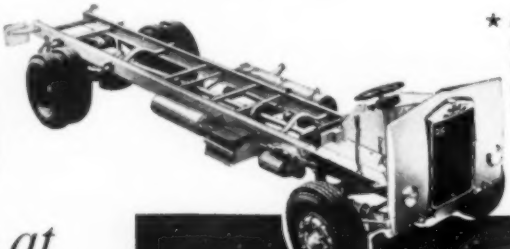

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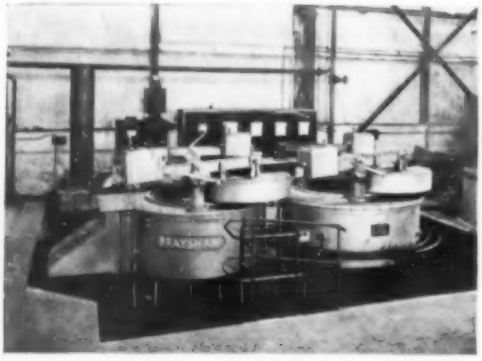

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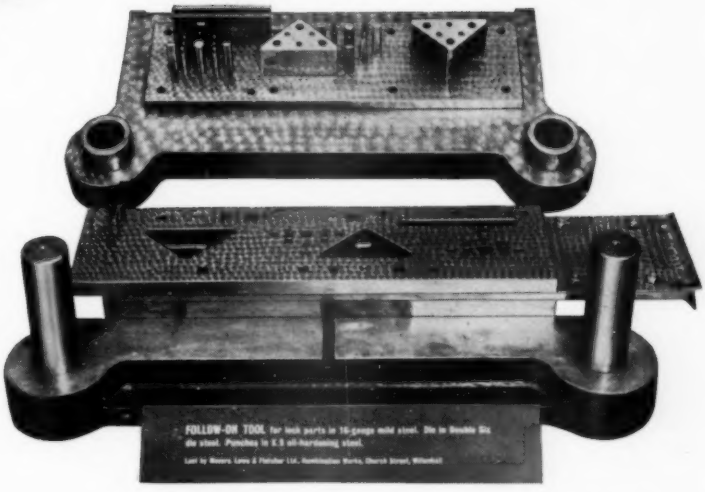

Follow-on Tool for lock parts in 16-gauge mild steel. Die in Double Six Die Steel. Punches in K9 oil-hardening steel.

Photograph by courtesy of Messrs. Low & Fletcher Ltd., Combination Works, Church Street, Willenhall.

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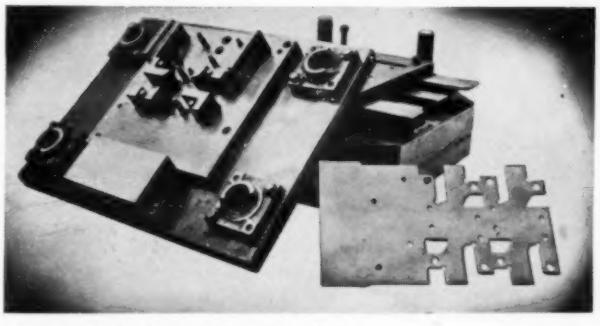

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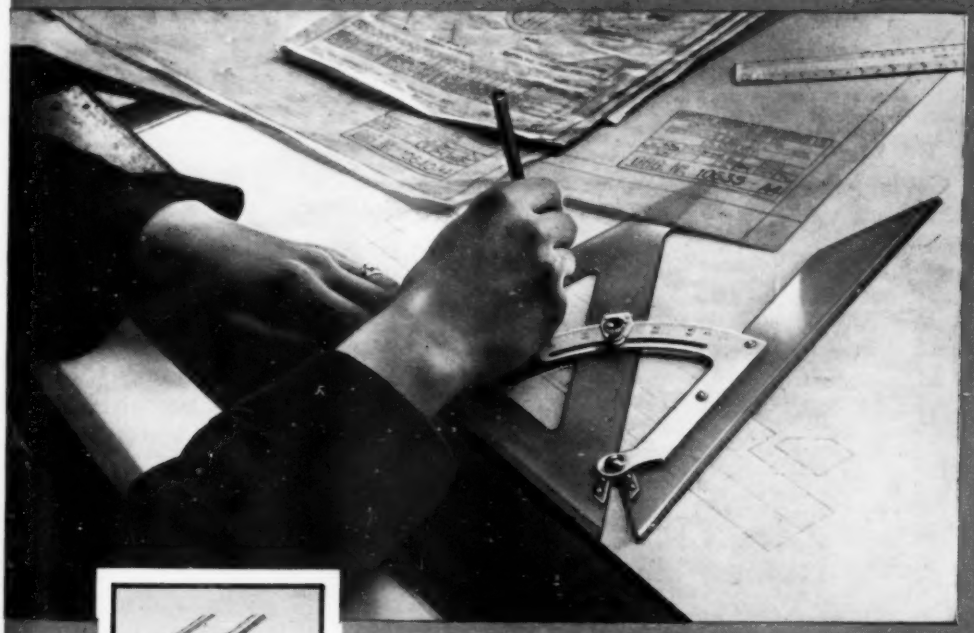

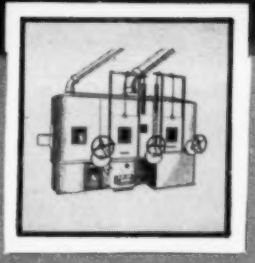

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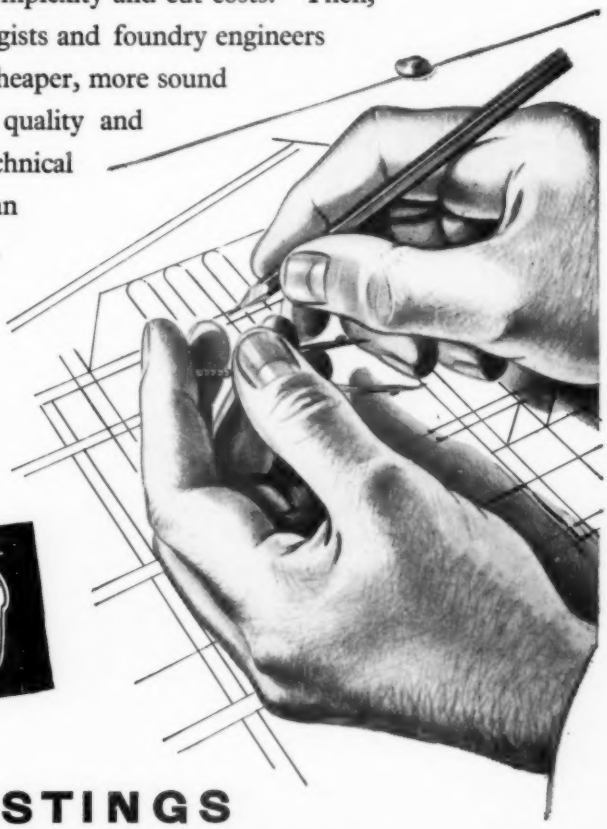

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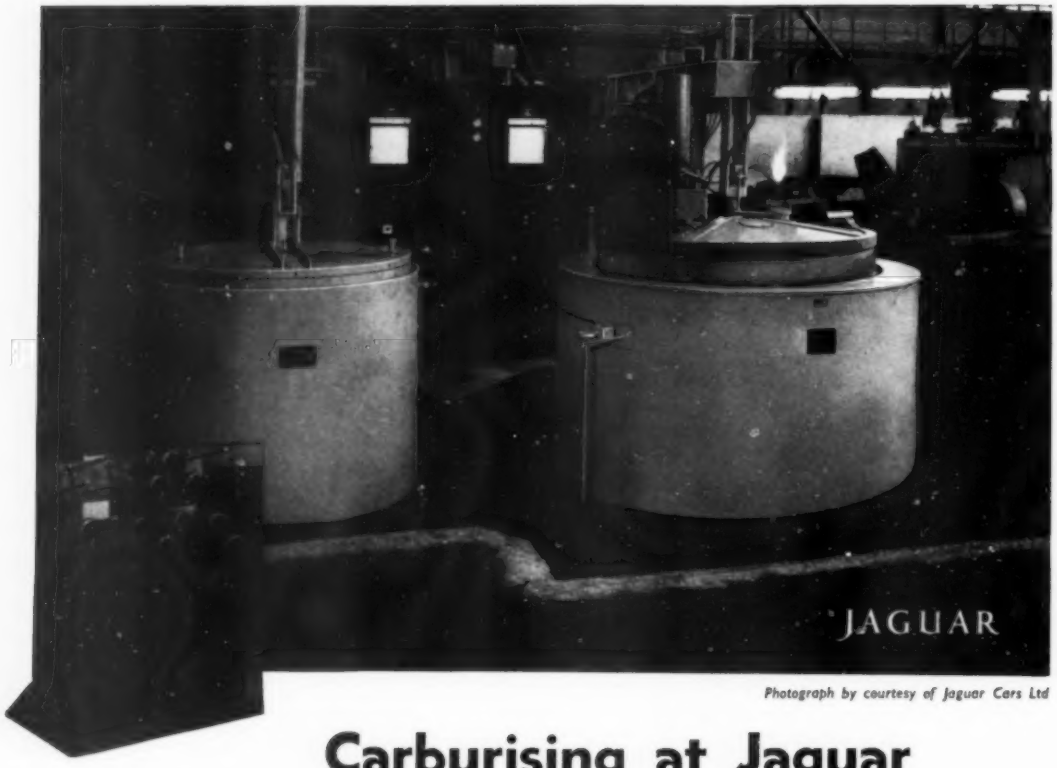

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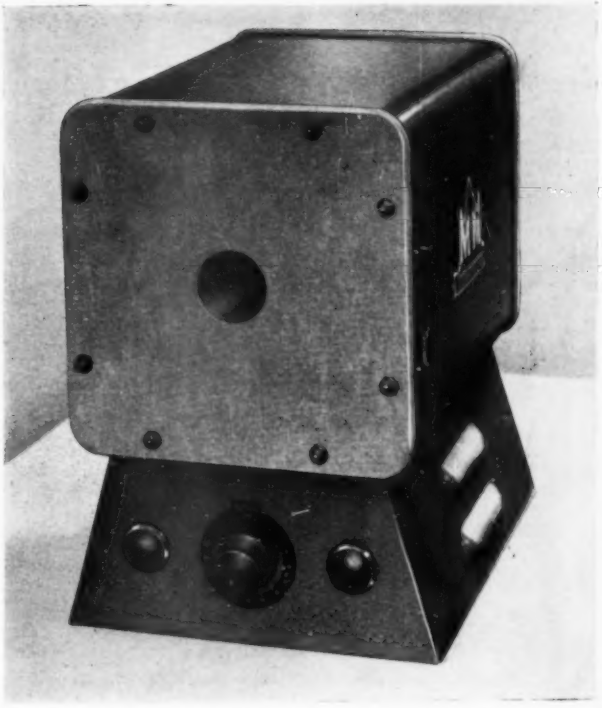

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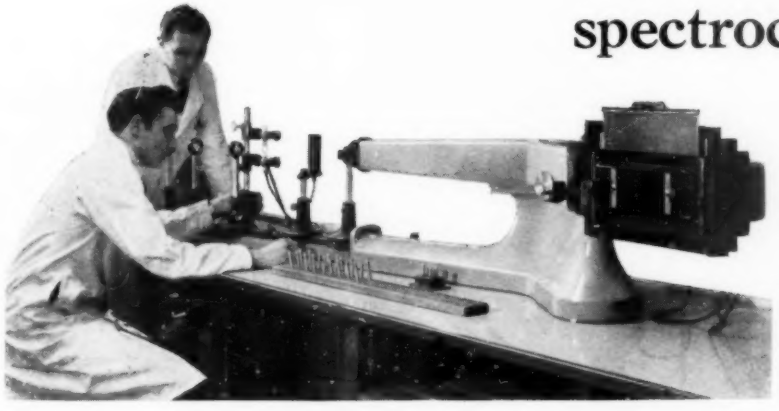

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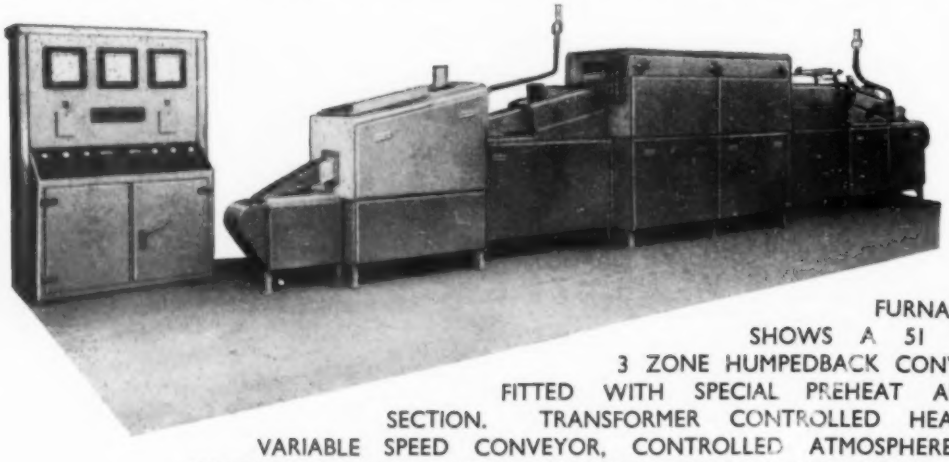

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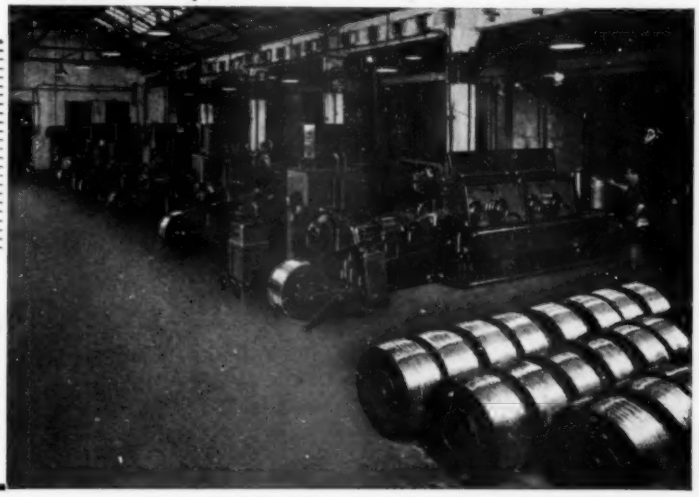

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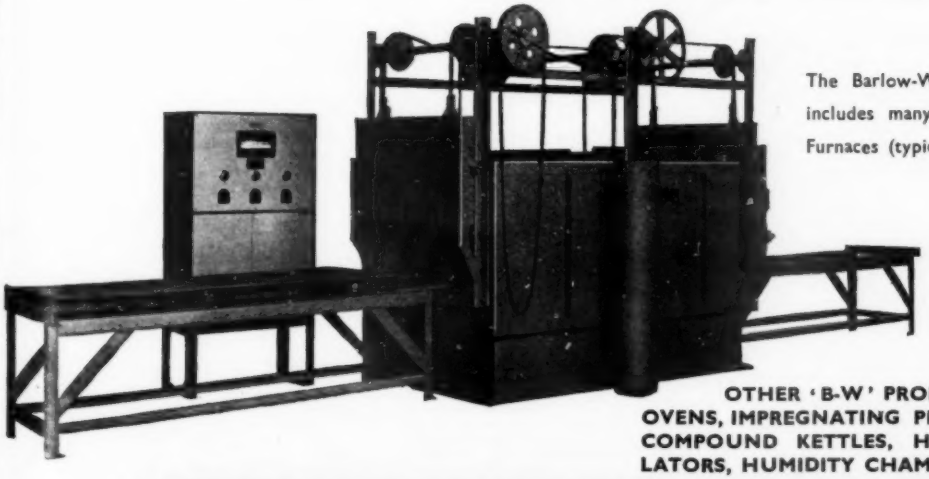

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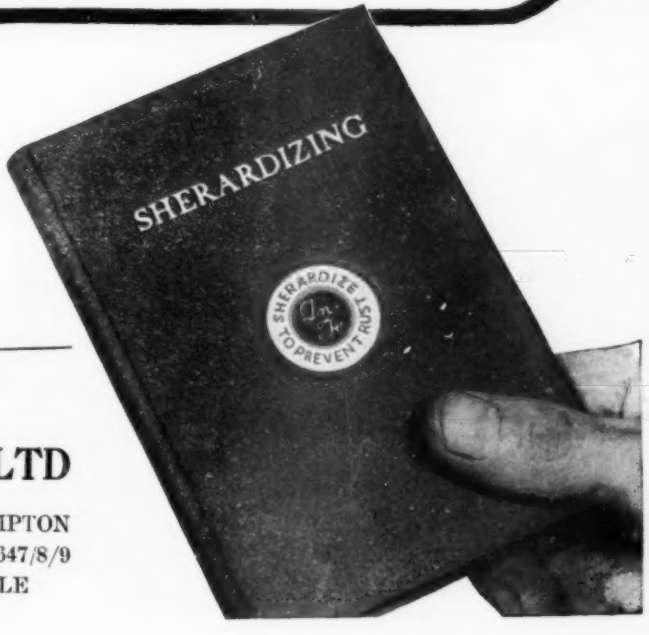

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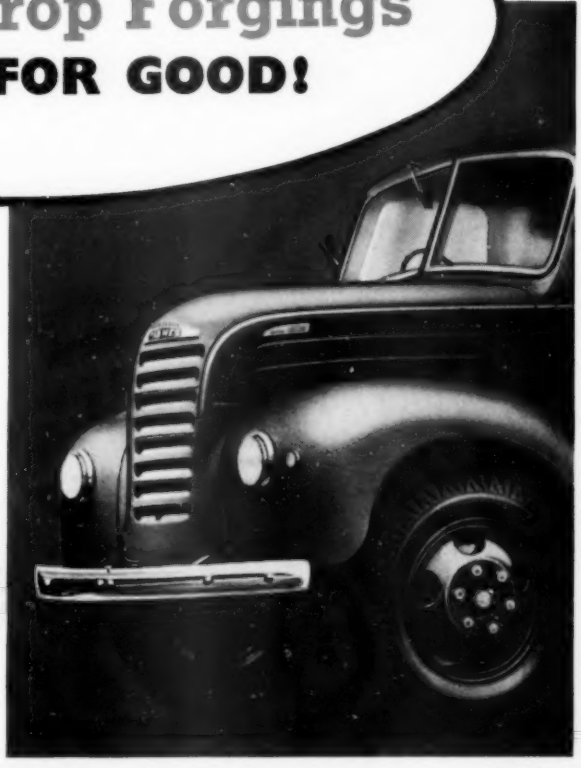

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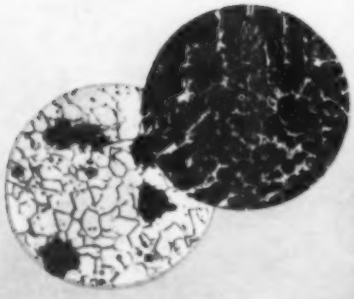

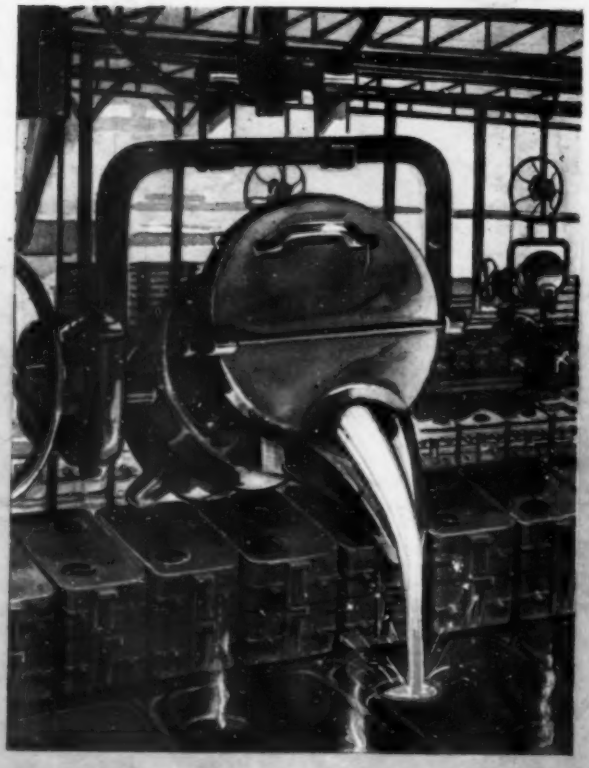

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